NEW

★TANKS ★JETS ★SUBS ★CHOPPERS ★BATTLESHIPS ★BOMBERS

HISTORY of WAR

AH-64 APACHE
★ LENGTH: 17.73M
★ TOP SPEED: 273KM/H

A-10 THUNDERBOLT II
★ ORIGIN: USA
★ FIRE RATE: 4,200/MIN

COMBAT MACHINES

VOLUME 1

PANAVIA TORNADO
★ ORIGIN: UK
★ ACTION: FIRST GULF WAR

TIGER I
★ RANGE: 5,000M
★ WEAPON: 88MM CANNON

AH-1Z VIPER
★ CREW: 2
★ COST: £18.8MN

M3 STUART
★ ORIGIN: USA
★ PRODUCED: 1940

VICKERS 6-TON
★ ORIGIN: UK
★ PRODUCED: 1929

INSIDE THE WORLD'S MOST INCREDIBLE MILITARY MACHINES

WELCOME TO

HISTORY OF WAR

COMBAT MACHINES

Since the outbreak of the First World War more than 100 years ago, the technology powering the world's military forces has evolved at an unprecedented pace. The introduction of the first tanks during the Great War marked the start of an arms race that has continued to this day, and as we get our first glimpse at the next generation of military machines, it's incredible to think how far technology has come.

In the History of War Book of Combat Machines, we chart the history and development of these awesome military vehicles, from the fearsome German Tiger tanks of the Second World War, to the rise of the nuclear-powered submarine, to the hi-tech fighter jets that now rule the skies across the globe.

We'll show you all the facts and figures you need to become a combat machine expert, as well as breaking down each vehicle to give you an inside look at the technology that makes these tanks, choppers and battleships tick.

Read on to discover how the combat machines of today were made, and what the latest advances in technology will mean for warfare in the years to come.

COMBAT MACHINES

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20 GREATEST MACHINES OF WAR

From the AK-47 to the Apache gunship, the military weapons and vehicles of the last century have transformed modern warfare on land, sea and air

The machines of the 20th Century were endlessly inventive and swung the pendulum for one side or another at crucial times. Just as a conflict looked as though it may grind to a stalemate, the order would be flipped on its head when a new invention made its timely debut on the battlefield.

The first machine guns brought about the end of marching in formation, while the arrival of the submarine blew the hierarchy of naval supremacy wide open. The most effective war machines are usually created as a response to seemingly unbeatable odds. The stealth bomber was invented to fight back against increasingly effective radar systems, while tanks protected against the deadly machine gun fire that cut down infantry divisions in droves.

From the fall of once great empires, to the first truly global conflicts and the rise of new superpowers, the last century produced increasingly effective and terrifying military technology. Listed here are just a few of the most devastating and revolutionary war machines that transformed the battlefields of one of history's bloodiest ever periods. Without the invention of these terrible but brilliant engineering marvels, the history of war would be very different indeed.

A stealth bomber on its first public flight in 1989. The B-2s cost a massive £86,100 ($135,000) per flight to operate

01 THE B-2 SPIRIT STEALTH BOMBER

IMAGINE AN AIRCRAFT ALMOST INVISIBLE TO RADAR THAT CAN STRIKE WITH EXPERT PRECISION FROM INCREDIBLY LONG RANGE. IT EXISTS, AND IT'S CALLED THE B-2

The world has come a long way since huge bombers blacked out the sky in the Second World War – now all you need is one. Among the most advanced of these bombers is undoubtedly the B-2 Spirit Stealth Bomber, which can reportedly do the job of 75 conventional aircraft. 21 of these modern aircraft were built (it would have been 132 if costs allowed) to strike heavily defended targets undetected.

An upgrade on the original Lockheed-Martin F-117 from 1981, its stealth is based on a smooth, contoured structure that keeps it partially hidden from radar. In addition, the bomber has systems that reduce its infrared, visual and electromagnetic visibility. A triumph of modern technology, underground bunkers can be struck by the craft's armaments and pilot error has been almost eliminated with the on-board computer, which also prevents stalls. All these features were put to deadly use over Kosovo in 1999 and Afghanistan in 2001, with precision attacks against munitions factories. Today the B-2 provides the USA with opportunity for lethal strikes.

Stealth bombers have the potential to reduce the size of air forces drastically due to their versatility and superior armament. Their presence in the latter days of the Cold War dissuaded the onset of full-scale war, as a single strike form a B-2 in retaliation would cause mass destruction. Its appeal to the US Air Force continues into the modern day, with the bombers set to receive a £6.3 billion ($9.9 billion) upgrade.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: USA
FIRST PRODUCED: 1989
WINGSPAN: 52.4M (172FT)
RANGE: 9,656KM (6,000MI)
TOP SPEED: HIGH SUBSONIC
WEAPONRY: NUCLEAR WARHEADS, ADVANCED CRUISE MISSILES, MARK-84 BOMBS

KEY TECHNOLOGY

The advent of fully working military radar systems during the Second World War marked the need for stealth technology. The B-2 makes itself only partially invisible to radar, as its unique design is excellent at reflecting signals at a different angle, rather than straight back to its receiver. Additionally, the dark colour absorbs high amounts of light, while the tiny iron spheres used on its surface paint dissipate the radar energy as heat, so only miniscule amounts make it back to the radio transmitter.

Design, shape and even texture helps B-2s avoid detection in a way that no craft has done before

02 MARK I TANK

THE FIRST TANK TO EVER SEE BATTLE CHANGED CONFLICT FOREVER, HELPING ELIMINATE THE STALEMATE OF TRENCH WARFARE

Only 250 of these metal beasts were created and even less saw battle on the muddy Western Front, but the Mark I signalled the dawn of a new type of warfare. With the stalemate of the trenches wearing down both sides in World War One, the tank was designed to be used as an armoured battering ram that could tear down enemy fortifications.

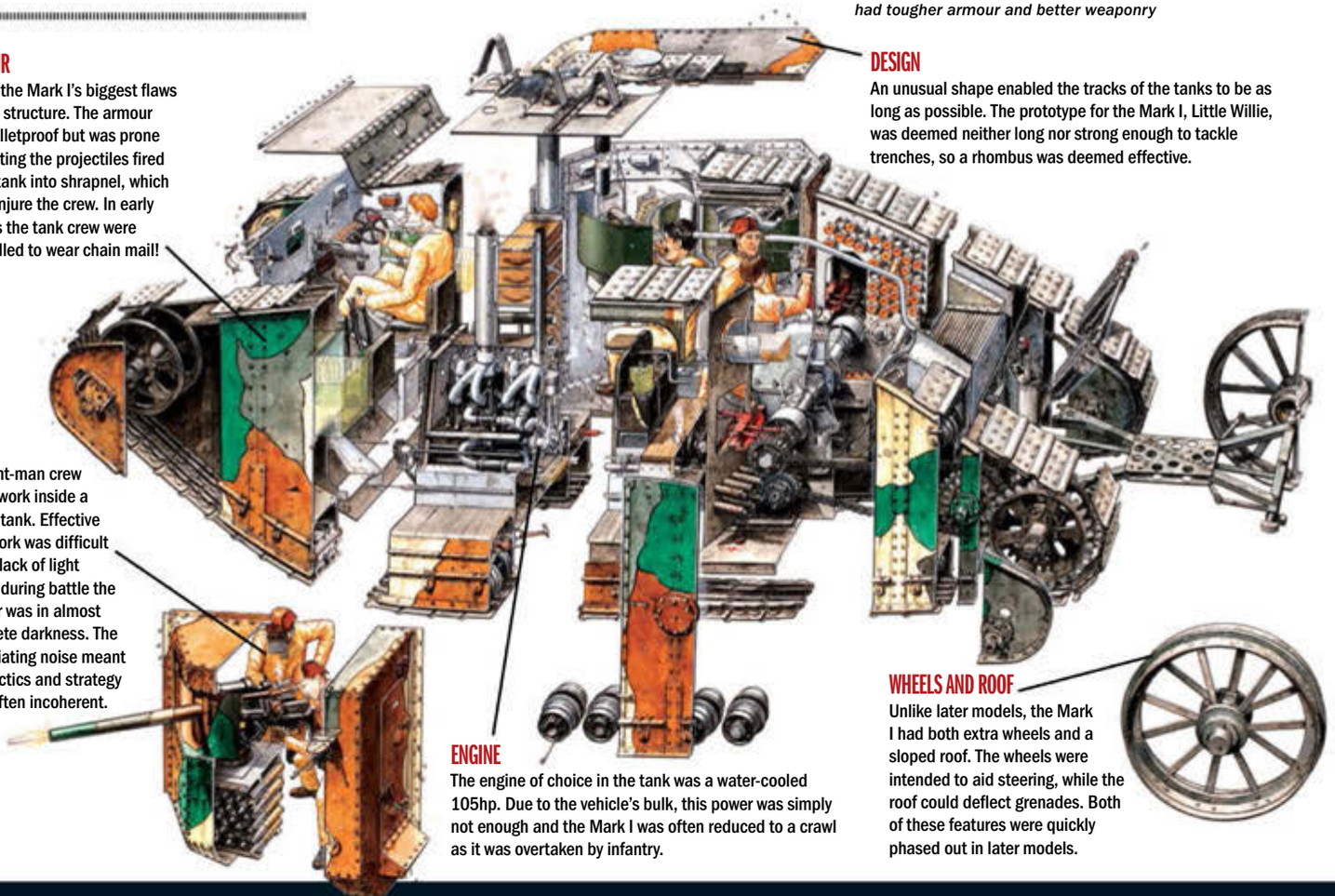
'Male' tanks were armed with three machine guns and one quarter-pounder gun, while the lighter 'female' versions contained six machine guns but less armour. The guns on the sides of this behemoth would mow down any infantry that would dare cross its path – at least that was the theory.

In its first few engagements, the Mark I regularly overheated and broke down and many were captured by the Imperial German Army. Conditions inside the tank were almost unbearable, with temperatures reaching 50 degrees Celsius (122 degrees Fahrenheit) and the loud machinery almost deafening.

As the war continued, improved versions were put into production, such as the Mark IV, which had tougher armour and better weaponry

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: GREAT BRITAIN
FIRST PRODUCED: 1916
LENGTH: 9.9M (32FT)
WEIGHT: 28 TONS
TOP SPEED: 5.9KM/H (3.2MPH)
WEAPONRY: TWO SIX-POUNDER (57MM) GUNS AND TWO AIR-COOLED MACHINE GUNS



ARMOUR
One of the Mark I's biggest flaws was its structure. The armour was bulletproof but was prone to splitting the projectiles fired at the tank into shrapnel, which could injure the crew. In early models the tank crew were compelled to wear chain mail!

DESIGN
An unusual shape enabled the tracks of the tanks to be as long as possible. The prototype for the Mark I, Little Willie, was deemed neither long nor strong enough to tackle trenches, so a rhombus was deemed effective.

CREW
An eight-man crew would work inside a Mark I tank. Effective teamwork was difficult as the lack of light meant during battle the interior was in almost complete darkness. The excruciating noise meant that tactics and strategy were often incoherent.

ENGINE
The engine of choice in the tank was a water-cooled 105hp. Due to the vehicle's bulk, this power was simply not enough and the Mark I was often reduced to a crawl as it was overtaken by infantry.

WHEELS AND ROOF
Unlike later models, the Mark I had both extra wheels and a sloped roof. The wheels were intended to aid steering, while the roof could deflect grenades. Both of these features were quickly phased out in later models.

HEAVY TANKS OF WORLD WAR ONE FROM THE MARK I TO THE MARK X

1915 'Little Wille' is tested as the first prototype of the Mark I – the precursor to all tanks.

April 1916 150 Mark I tanks are ordered to be built for the war in the trenches.

August 1916 The first batch of Mark I tanks make their debut just in time for the Somme offensive.

March 1917 The first Mark II tanks enter the fray, ready made with improvements over the original model.

May 1917 The vastly improved Mark IV is introduced onto the Western Front after the Mark III is used purely for training purposes.

July 1917 The new Mark VII is born after co-development with the USA. The VI had previously been cancelled after disagreements arose during production.

November 1917 476 tanks do battle at Cambrai and make significant advances into German territory across the Hindenburg Line.

April 1918 The first ever tank-to-tank battle sees Mark IVs combat German A7Vs.

September 1918 The Mark VIII is created after a joint project between the USA, Britain and France and remains in use until 1934.

1919 The last two 'Mark' models are created, with the IX a troop carrier. The X never makes it off the production line.

"TANKS STILL PLAY A MAJOR PART IN CONFLICTS ACROSS THE GLOBE – THE MARK I IS WHERE THEY ALL BEGAN"

The potential was seen in the Mark I though, so later versions of the tank would succeed where it failed. After small advances in the II and III, the Mark IV was a vastly improved machine. Containing much thicker armour and a better engine, this would have the greatest impact on the Western Front, with its successor only available in the latter stages of the war.

The tank became the new cavalry of the battlefield, and the various 'Mark' models played a big part in the emergence of tank dominance. The Mark IX was the final tank of the line to be built, but the design was still used after the Great War. Mark Vs were used by both sides in the Russian Civil War and two were even found in the Battle of Berlin in the last days of the Third Reich.

Although initially unreliable, these tanks were pioneers for modern warfare. During the Battle of Kursk in 1943 over 6,000 tanks duked it out on the battlefield. The Nazi blitzkrieg would have stalled without them, and during the post-World War years, tanks still play a major part in conflicts across the globe – the Mark I is where they all began.

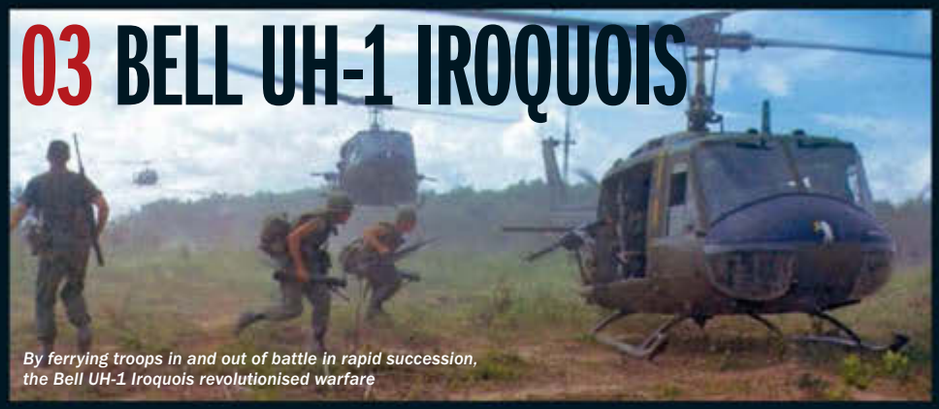
The tank was a steep learning curve, so it included many different features, such as back wheels and extra roof protection

IN ACTION
THE BATTLE OF CAMBRAI: GIANT STEPS IN CATERPILLAR TRACKS

By late 1917 the role of tanks was increasing after many failed attempts to incorporate the mechanical monster in warfare. After struggling in the mud pits of the Somme, the dry plains of Cambrai were ideal for tank tracks.

The attack began on the morning of the 20 November as 476 of the machines advanced on German positions. The surprise attack was a resounding success, with German forces pushed back by 3.7 miles (6km) as the Hindenburg Line was breached for the first time during the war. On the first day alone, 8,000 prisoners and 100 guns were taken. However, a German counterattack nullified a sizeable portion of the British gains, as the deployment of tanks didn't quite wear down the German resistance completely. Nonetheless, the effectiveness of tanks had finally been proved and it was from here on out that the machine became an essential instrument of war.

03 BELL UH-1 IROQUOIS



By ferrying troops in and out of battle in rapid succession, the Bell UH-1 Iroquois revolutionised warfare

Nicknamed the Huey, this popular vehicle machine was vital for the deployment of American troops during the Vietnam War. Powered by a jet turbine that had never been installed on a helicopter before, 16,000 of these small vehicles were made and are still in use by the US Drug Enforcement Agency (DEA). These multipurpose helicopters could ferry up to 14 soldiers to and from battlefields. M-240 and Browning guns could also be attached.

04 TIGER II

The Tiger II was beset by manufacturing issues after being rushed off the Third Reich production line in an attempt to save the war

One of the deadliest tanks of the entire Second World War, the Tiger II would have dominated the battlefield if it weren't for its inherent production flaws. Feared by the Allied forces, this armoured beast quickly earned an aura of invincibility because of its thick armour and deadly 88mm turret gun. After the war, German Tiger II technology and prototypes were used for the future tanks of the 20th Century.

05 C-130 HERCULES

The C-130 is used in a variety of missions, from cargo drops, to humanitarian efforts to troop deployment

Since its first flight in 1955, there hasn't been a military aircraft quite as reliable and adaptable as the Hercules. Currently operated by over 16 countries, the C-130 can carry various payloads up to over 20,000kg. Capable of operating over a range of 3,800km, it also fulfils the role of a long-distance cargo and transport aircraft perfectly, and there's still seemingly no need to replace it, even after 60 years in service.

06 M1 ABRAMS MEDIUM BATTLE TANK

A VETERAN OF WARS ALL OVER THE GLOBE SINCE 1979, THIS MACHINE HELPED SHUNT ARMOURED GROUND WARFARE INTO THE MODERN ERA

The M1 Abrams battle tank was born after many failed attempts by the USA and Germany to create a tank to rival the Soviet T-72. By 1979 the US had decided to go solo and the outcome was the M1 Abrams, which excels in the three key areas of tank warfare: firepower, protection and mobility. It was produced six years after the Yom Kippur War, which saw the largest tank battle since the Second World War. An all-weather vehicle, it still plays a major role in the US Army, with the ability to go head-to-head with other armoured vehicles, while providing infantry support and mobile firepower.

It served during the Gulf War, in Afghanistan and the 2003 invasion of Iraq. In all these conflicts the Abrams outclassed its rivals with superior range, night vision and thermal sight capabilities.

Only nine were put beyond repair in the whole of the Gulf War and the tank was essential to the success of Operation Desert Storm. Nearly 9,000 have been constructed for use worldwide and it's still in production after 35 years. Many have described it as being the first US tank to outclass its Soviet equivalent and many variants on the original design have been made due to its success. The model M1A2 is undoubtedly the most advanced tank operating in the world today.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: USA
FIRST PRODUCED: 1979
LENGTH: 9.83M (32.25FT)
WEIGHT: 63,000KG (139,080LB)
TOP SPEED: 67KM/H (42MPH)
WEAPONRY: 120MM MAIN GUN, 12.7MM BROWNING M1HB ANTI-AIRCRAFT HEAVY MACHINE GUN, 2X 7.62MM M240 MACHINE GUNS, 2X 6 SMOKE GRENADE DISCHARGES

Above: *With tough armour all over, the M1 Abrams is highly resistant to most gun and missile fire*

Below: *The power of the Abrams' 105mm main gun has been upgraded to a 120mm version on the M1A1 and M1A2*

KEY TECHNOLOGY

A tough duo of rolled homogeneous steel plates and Chobham laminate, keep the tank and its crew well protected. Both HEAT warheads and Sabot rounds cannot puncture the inner layer of the tank and the structure also prevents injury by having armoured storage for the tank's own armaments. Better still, and much more inconspicuous, is an air-purification system dedicated to repelling biological attack.

07 AK-47 ASSAULT RIFLE

A COMBINATION OF A SUBMACHINE GUN'S FIREPOWER, WITH ALL THE ACCURACY OF A RIFLE

The distinctive curved magazine of the AK-47 is a common sight, with an estimated 100 million having been manufactured

The StG 44 was a German assault rifle produced at the tail end of World War Two. If it were produced earlier, it would arguably have had a drastic affect on the fortunes of the Third Reich – that's how advanced it was. Combining the best qualities of a submachine gun and a rifle, it was one neat package of destruction. The Allies needed an answer – it came in 1947 in the form of the AK-47.

Created in the USSR by inventor and engineer Mikhail Kalashnikov, the weapon's ability to fire intermediate power cartridges at a rapid rate put it head and shoulders above the competition and paved the way for a wave of assault rifles such as the M16 and FAMAS.

It saw widespread action in the Korean War and was only upstaged in the Russian military by the mid-1970s with the development of the AK-74. There have even been stories that during the Vietnam War, US GIs stole AK-47s from the Viet Cong as they were still superior to the American equivalents. Currently, it's the weapon of choice for militant groups the world over due to its low cost and general all-round effectiveness. More AK rifles have been produced than all the other assault rifles combined and it remains a key player in warfare.

KEY TECHNOLOGY

The AK-47 was a phenomenon in so many ways and raised the bar in land warfare. The next stage of assault rifle evolution after the StG 44 took the first steps – its selective fire enabled it to be used in all areas of war, from street-to-street skirmishes to raids on fortified positions. An incredibly basic weapon for all its advances, the rifle only weighs four kilograms (9lbs). It can be stripped and cleaned in under a minute, making it invaluable for tense battlefield situations.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: SOVIET UNION
FIRST PRODUCED: 1947
LENGTH: 88CM (35IN)
ACTION: GAS-OPERATED ROTATING BOLT
RANGE: 400M (1310FT)
AMMUNITION: 7.62X39MM ROUNDS

08 THE BLACKBIRD

Originally kept under wraps as a US and UK secret Black Project, the Lockheed SR-71 Blackbird was a technological wonder. The fastest plane of all time (reaching an eye-melting 2,530km/h (2,193mph), it was also one of the highest-flying military aircraft ever made. The plane was so fast, it even broke both the sound and heat barriers and required a specialist fuel and titanium structure to fly.

Devised after the U2 incident in 1960, the Blackbird demonstrated that the US needed a quicker and higher-flying reconnaissance aircraft that couldn't be tracked by the USSR. The designers of the Blackbird described it as their hardest ever assignment, as the plane was so different and advanced compared with anything that came before. 32 were constructed in total and served as scouting aircraft for over 30 years. The details of a vast majority of these missions are still classified.

The altitude and speed of the Blackbird meant pilots were forced to wear astronaut-like suits that protected them from the elements

09 ENIGMA MACHINE

Highly sophisticated devices for their time, Enigma machines held the key to many of the Wehrmacht's secrets. An electro-mechanical rotor cipher machine, the device was used by the Third Reich to transport and receive covert messages and tactics without the risk of being decoded.

Capable of millions of combinations, the Allies captured many of these messages but were only able to break the code in 1940 with the help of Polish experts from the Government Code and Cypher School (GC&CS) in Bletchley Park, England. The code was eventually broken by using a device called a Bombe, which could attempt hundreds of potential codes per minute until it found the correct combination.

It has been speculated that this breakthrough shortened the war by up to two years, such was the effectiveness and importance of the machine.

The Enigma machine was so effective, British agents had to play down their successes so the Axis powers didn't get wind of their discovery

10 AH-64 APACHE ATTACK HELICOPTER

THIS HELICOPTER GUNSHIP IS THE TANK'S WORST ENEMY AND CAN ELIMINATE VAST SWATHS OF HEAVY INFANTRY IN SECONDS

The AH-64 has the ability to hover in wait and then unleash Hellfire and Hydra missiles to eliminate targets

Since their inception in the late 20th Century, advanced attack helicopters have been a nightmare for troops both on land and at sea – the most notable of these is the AH-64 Apache.

Prior to attack helicopters, infantry could advance along territory, with infrequent air strikes from bombers being their only airborne concern. Now, with a chain-gun-equipped helicopter prowling the skies, tactics and strategies have become very different. The AH-64 can be assigned to almost any mission, from destroying fortifications, to delaying and disrupting the movement of troops. It's even more dangerous at night, with the help of Target Acquisition Designation Sight (TADS) and Pilot Night Vision Sensors (PNVS).

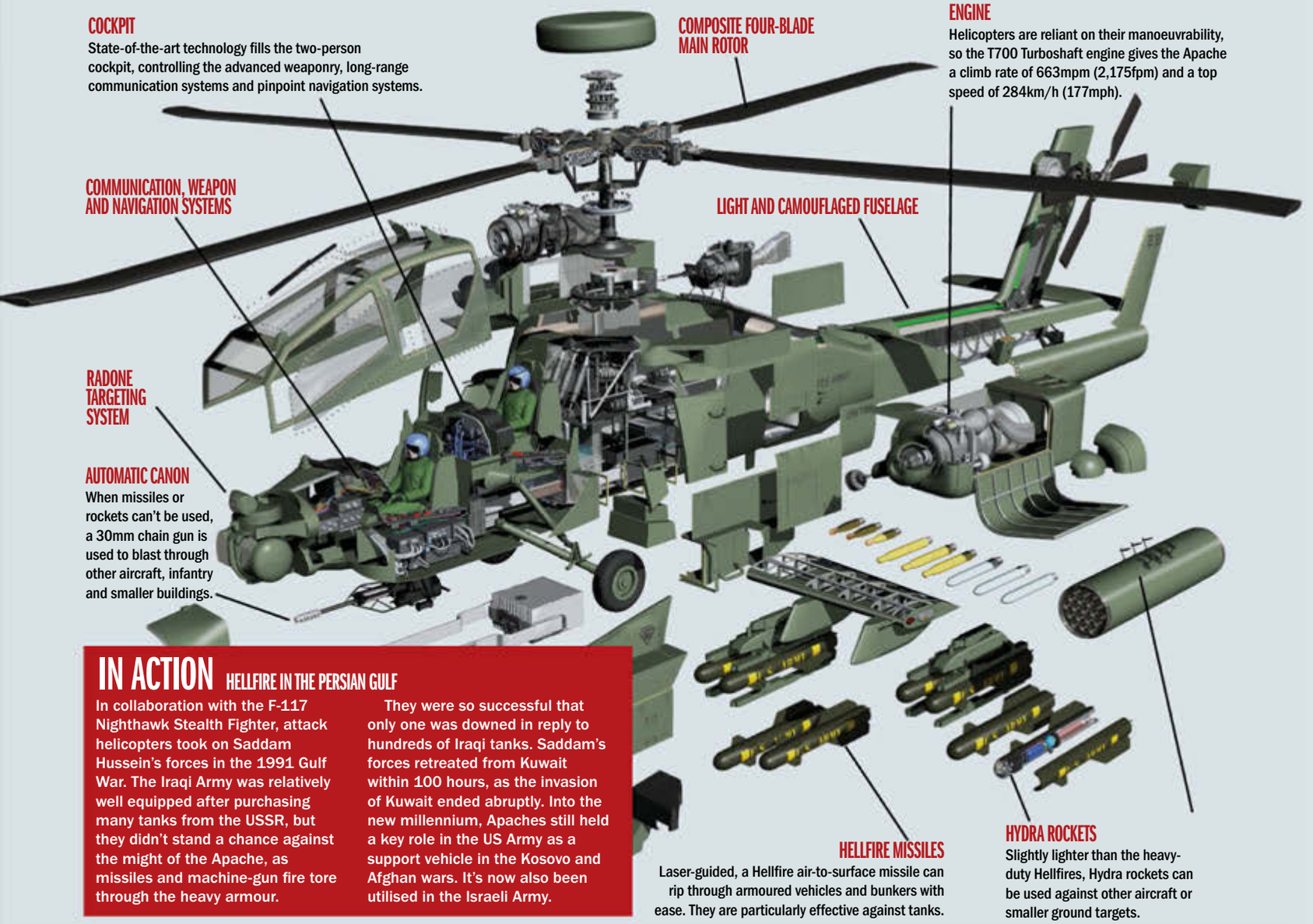
The gunship's M230 chain gun can strafe and lay waste to infantry, while Hellfire missiles can take down armoured vehicles, ships and structures. If the Apache is threatened from the air, its Hydra rockets will combat most aerial rivals. The US Army has ordered over 800 of the machines since they were first introduced, while others have found their way into the Israeli and Egyptian air forces. The advanced attack helicopter reached its zenith in Operation Desert Storm, where it was used to decimate 500 Iraqi tanks and other armoured vehicles.

Apaches have a rapid response rate to enemy threats, and can be deployed far quicker than land-based vehicles. Additionally, the gunship requires far less space and fewer resources than fighter jets. The AH-64 can also be called upon in all manner of inhospitable conditions.

Naturally, various methods have been devised to combat the attack helicopter, and militants that come into contact with the Apache now carry rocket-propelled grenades.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: USA
FIRST PRODUCED: 1983
LENGTH: 17.73M (58.17FT)
WEIGHT: 7,270KG (16,027LB)
TOP SPEED: 149KN (273KM/H/170MPH)
WEAPONRY: HELLFIRE LASER-DESIGNATED MISSILES, M230 CHAIN GUN, HYDRA ROCKETS



COCKPIT
State-of-the-art technology fills the two-person cockpit, controlling the advanced weaponry, long-range communication systems and pinpoint navigation systems.

COMPOSITE FOUR-BLADE MAIN ROTOR

ENGINE
Helicopters are reliant on their manoeuvrability, so the T700 Turboshaft engine gives the Apache a climb rate of 663mpm (2,175fpm) and a top speed of 284km/h (177mph).

COMMUNICATION, WEAPON AND NAVIGATION SYSTEMS

LIGHT AND CAMOUFLAGED FUSELAGE

RADONE TARGETING SYSTEM

AUTOMATIC CANON
When missiles or rockets can't be used, a 30mm chain gun is used to blast through other aircraft, infantry and smaller buildings.

HELLFIRE MISSILES
Laser-guided, a Hellfire air-to-surface missile can rip through armoured vehicles and bunkers with ease. They are particularly effective against tanks.

HYDRA ROCKETS
Slightly lighter than the heavy-duty Hellfires, Hydra rockets can be used against other aircraft or smaller ground targets.

IN ACTION HELLFIRE IN THE PERSIAN GULF

In collaboration with the F-117 Nighthawk Stealth Fighter, attack helicopters took on Saddam Hussein's forces in the 1991 Gulf War. The Iraqi Army was relatively well equipped after purchasing many tanks from the USSR, but they didn't stand a chance against the might of the Apache, as missiles and machine-gun fire tore through the heavy armour.

They were so successful that only one was downed in reply to hundreds of Iraqi tanks. Saddam's forces retreated from Kuwait within 100 hours, as the invasion of Kuwait ended abruptly. Into the new millennium, Apaches still held a key role in the US Army as a support vehicle in the Kosovo and Afghan wars. It's now also been utilised in the Israeli Army.

FLYING ON THE FRONTLINE

MAJOR ALEX HARRIS OF THE UK ARMY AIR CORPS SHARES HIS EXPERIENCES OF FLYING APACHE AIRCRAFT

HOW LONG DOES IT TAKE TO TRAIN TO FLY AN APACHE? IS IT INITIALLY DIFFICULT TO HANDLE?

You first have to complete the army pilot's course, which is modular and takes about two years. Once you have been awarded your army flying wings you might get selected to train on the Apache. The first part is called Conversion to Type (CTT), which teaches you how to fly the aircraft and lasts about six months. If successful, you move on to the next phase which is called Conversion to Role (CTR). This teaches you how to fly the aircraft in all scenarios and also lasts six months.

The culmination is the live firing of all the Apache weapon types in Arizona, USA. You are then a qualified Apache pilot. Even after all of that, you are constantly learning and attending different courses. These could be such things as learning to operate from a Royal Navy ship, or becoming a weapons instructor. Initially it can be quite difficult to fly, as it's much larger and more complex than the training aircraft.

The courses are all progressive though and you can't advance until you have mastered the basics. The aircraft has a very good stabilisation system to ensure that it's a steady platform from which to launch weapons, so when these are working for you it is a great aircraft to fly.

WHAT WAS THE APACHE'S ROLE IN THE THEATRES YOU FLEW IN AND HOW EFFECTIVE WAS IT?

It's main role was to support the ground forces with precision weapons when they got engaged by the Taliban and were pinned down. With a talk on over the radio from the ground forces, the Apaches were able to identify the enemy, single them out from the population and built-up areas, before decisively engaging them.

We also escorted the Chinooks that carried the Medical Emergency Response Team (MERT). This life-saving asset often picked up seriously wounded casualties from the battlefield while the firefight still went on around them. They were a big target for the Taliban and it was our job to try and destroy the enemy before they could engage them.

DOES THE HELICOPTER FORM PART OF A SQUAD OR IS IT FLOWN SOLO WHEN ON THE ATTACK?

Although they can work alone, Apaches would normally work as a pair. This is known as a Flight. During an engagement one aircraft would act as the shooter and the other as the looker. This means that while one is zoomed in on the target, the other aircraft is looking out wider for more targets in depth.

The looker will also put himself in a position to follow up on the first aircraft's attack if necessary. If the Squadron is fighting together you may find two or more Flights working in an engagement area to prosecute targets.

HOW DOES YOUR CO-PILOT ASSIST YOU?

While the Co-Pilot Gunner is heads-down in the sight looking for enemy, the pilot is looking after the safety of the aircraft. He is monitoring the systems and ensuring that all is as it should be, but more than that he is watching for any close-in enemy trying to shoot them down. With the Helmet Mounted Display, the pilot is only a couple of button presses away from firing the 30mm. It can be slaved to his head position so that wherever he looks, all he has to do is pull the trigger and he is firing on-target.

HAVE YOU EVER HAD TO MAKE A EMERGENCY LANDING?

In Afghanistan on Very High Readiness (VHR) we got a call to go and support some ground forces who were under fire. However, not long after take off, one of our two engines developed a serious fault and started to break up, so we had to shut it down. Because of the weight of the weapons we had on board and the fact that our performance was low in the hot and high conditions, we were unable to maintain level flight and so started to descend to the desert floor.

We worked out that we could just about make it back to Camp Bastion before we would hit the deck, so we nursed it back to the Apache landing strip, landed on and parked up. We jumped straight out of that one and moved our kit into the aircraft next to it, getting back out in under five minutes. We eventually got to the site of the battle and were engaging with hellfire missiles and 30mm within minutes of arriving.

WHAT WAS YOUR MOST MEMORABLE FLIGHT?

Probably the first time I ever fired the weapons in a combat situation. We were fighting in the middle of a city and some enemy armed with heavy weapons and suicide vests had taken over the top two floors of a hotel that overlooked a friendly camp. They were firing down into the camp and causing friendly casualties. We arrived not long after it began and I remember thinking that if I got this wrong in such a built-up area, then the consequences could be terrible. However, the training soon kicked in and operating as a crew and as a Flight, we successfully defeated the enemy. I do remember afterwards that the hotel had some serious holes in it and I'd have some explaining to do when I got back to base.

11 HMS DREADNOUGHT

THE DAWN OF THE FIRST DREADNOUGHT BATTLESHIP REVOLUTIONISED NAVAL WARFARE PRIOR TO TWO WORLD WARS

If there's one war machine that demonstrated the intensity of the Anglo-German arms race, it was the Dreadnought class of battleship. The first, HMS Dreadnought, was completed in 1906 and completely eclipsed what came before. With its steam turbine powerplant, it could roar through the waves at high speeds while aiming the most heavily-armed naval guns in history at an enemy vessel. It was the first vessel to focus entirely on 'big gun' armament, which had a range of a massive 22.8 kilometres (14.2 miles). The guns were controlled by all-new electronic transmitting equipment that could aim the artillery incredibly accurately for the time.

Dreadnought was even the first ship to house the captain and officers nearer the bridge at the front, unlike the old style seen on tall ships in the age of sail. With such advanced armament and technology, the design became immensely popular and by 1914 the Royal Navy had constructed 19, while the Imperial German Navy had 13 in its fleet. The impact was so great that only a year later 'Super-Dreadnoughts' were being produced. The Dreadnought class had revolutionised the war at sea and a constant stream of updated models would follow right up until the height of the Cold War, when nuclear submarines began to change naval combat once again.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: GREAT BRITAIN
FIRST PRODUCED: 1906
LENGTH: 160M (525FT)
WEIGHT: 18,400 TONNES
TOP SPEED: 21 KNOTS (39KMH/24MPH)
WEAPONRY: TEN 305MM GUNS, 24 76MM GUNS, FIVE TORPEDO TUBES

KEY TECHNOLOGY

Without the steam turbine, the Dreadnought class of battleships would have not been the significant machine it was. The innovative technology was a British invention from 1884, but this was the first time it would be used on a warship. The system replaced the triple-expansion engine that had been used so extensively in older ships and made the HMS Dreadnought the fastest battleship in the world. With the new mechanism, the battleship now had a range of approx 12,260km (7,620mi).

The Minigun enabled a weapon with the power of the M61 Vulcan to be used on ships, turrets and armoured vehicles

12 M61 VULCAN

THE GATLING GUN OF THE MODERN ERA, THE M61 VULCAN SHOWCASES THE TRUE POWER OF CONTEMPORARY HAND-OPERATED WEAPONS

A gigantic weapon of war, the M61 Vulcan was initially devised as an anti-aircraft gun. Its rotating six-bolt barrel gives it a much higher rate of fire and reliability than single-barrel machine guns, which would overheat after persistent use.

An ammo belt was originally used to feed the bullet-hungry firearm, but after a jamming problem the belts were replaced by a linkless feed system. The gun is powered both hydraulically and electrically by aircraft and can fire both incendiary and armour-piercing rounds. The invention of the weapon gave fighter jets an alternative to using missiles at short range and has one of the highest firing rates of any machine gun. The M61 has also been used on the ground as an air defence system in armoured vehicles and its successor, the M134 Minigun, was used in helicopters as a response to RPG fire from the ground.

The M134 has made the weapon class much more effective, as it can be placed on gun emplacements. This scaled-down version of the original made the weapon more readily transportable but with a decreased rate of fire. Despite its inability to be carried and fired by a single infantryman (as is often the myth), the M61 Vulcan has made all types of military aircraft much more resistant to ground fire and more effective at taking out ground units. Its high rate of fire means successful hits are achievable even at jet speeds.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: USA
FIRST PRODUCED: 1959
LENGTH: 182CM (72IN)
ACTION: HYDRAULICALLY OPERATED BELT-FED UNIT
RATE OF FIRE: 6,000 ROUNDS PER MINUTE
AMMUNITION: 20X102MM ROUNDS

KEY TECHNOLOGY

Overheating was always an issue with machine guns with a high rate of fire, but the M61 Vulcan managed to remedy this downside. By using six separate barrels firing 1,000 rounds a minute, none of the systems would overheat or malfunction but 6,000 rounds of ammunition would still be fired off in a minute's worth of firing. This was extremely useful on military aircraft where a fault could not be fixed mid-flight.

13 B-52 STRATOFORTRESS

This gigantic bomber was one of the biggest and most-powerful aircraft ever made. Powered by eight engines, its original purpose was to carry atomic bombs behind the Iron Curtain if relations with the Soviet Union soured. Thankfully, it never had the opportunity to deploy its one-megaton nuclear warhead, so it was confined to bombing missions using conventional munitions.

It proved to be very versatile plane, carrying up to 27,216 kilograms (60,000lbs) of bombs ranging from nuclear to precision-guided cruise missiles. The B-52 was hugely effective during Vietnam and the Gulf Wars and its descendants have been in frequent use in Iraq and the Balkans. The plane's sheer bulk means that the B-52 is also used as a carrier for air rocket launches. The success of this war machine has meant that it's now the longest-serving bomber in US military history and is set to remain in operation until 2040.

The B-52 is an exceptional air launcher. Here it is (inset) carrying two Lockheed D-21 reconnaissance drones

14 HUMVEE

The HUMVEE saw widespread use in the Gulf War and has become and integral part of the US Army since

After the Vietnam War, the aging US M151 jeep was in drastic need of an upgrade. The result finally came in the early 1980s, when the High Mobility Multipurpose Wheeled Vehicle (HMMWV/HUMVEE) was developed.

Designed as an infantry support vehicle, the HUMVEE features great all-round capabilities and could even be dropped into battle from the air. Lightweight and four-wheel drive, the vehicle is highly flexible and can perform a variety of battlefield and reconnaissance roles. It provides an essential middle ground between surveillance and the heavy artillery rolling in.

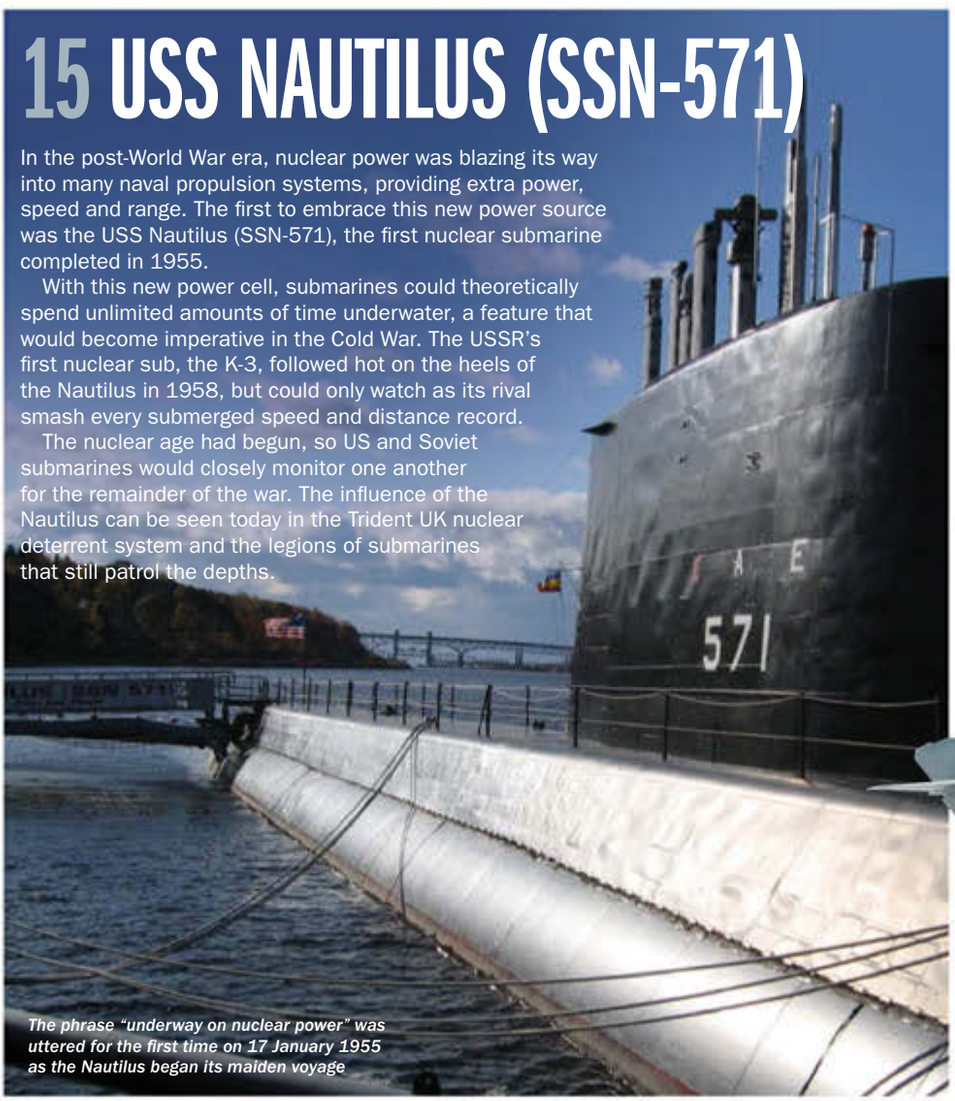
A HUMVEE can carry a variety of equipment, from machine guns to missile launchers, and so can also act as a store for weaponry and ammunition. Since its inception there have been numerous improvements on the original design, and the vehicle has subsequently become a staple of the US Army.

15 USS NAUTILUS (SSN-571)

In the post-World War era, nuclear power was blazing its way into many naval propulsion systems, providing extra power, speed and range. The first to embrace this new power source was the USS Nautilus (SSN-571), the first nuclear submarine completed in 1955.

With this new power cell, submarines could theoretically spend unlimited amounts of time underwater, a feature that would become imperative in the Cold War. The USSR's first nuclear sub, the K-3, followed hot on the heels of the Nautilus in 1958, but could only watch as its rival smash every submerged speed and distance record.

The nuclear age had begun, so US and Soviet submarines would closely monitor one another for the remainder of the war. The influence of the Nautilus can be seen today in the Trident UK nuclear deterrent system and the legions of submarines that still patrol the depths.



The phrase "underway on nuclear power" was uttered for the first time on 17 January 1955 as the Nautilus began its maiden voyage

16 ZUBR-CLASS LCAC MILITARY HOVERCRAFT

The largest class of military hovercraft in the world is the Zubr, which became an important part of warfare after its inception in 1988. Providing the same role that transport helicopters do for ground troops, the Zubr can sealift men, tanks and other armoured vehicles right up to the shoreline coastal assaults.

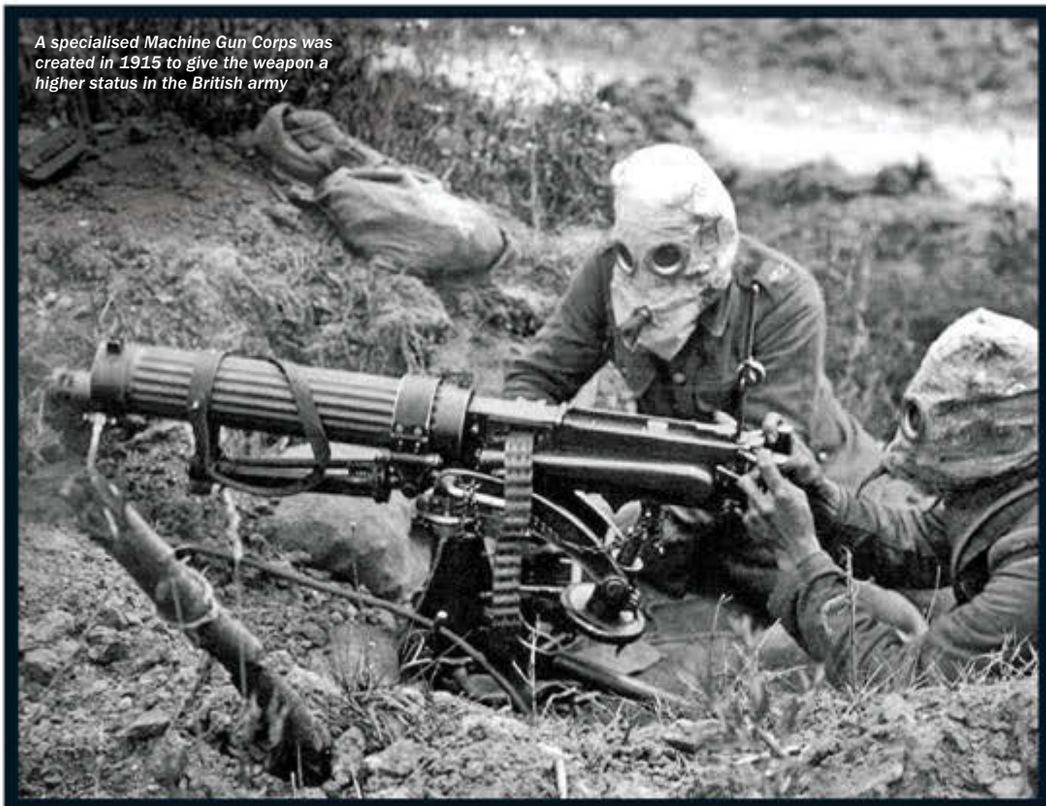
There are currently nine in this class of military hovercraft in active service within the Russian, Ukrainian and Greek navies

"THE ZUBR CAN SEALIFT MEN, TANKS AND OTHER ARMOURED VEHICLES RIGHT UP TO THE SHORELINE"

17 MIG-15

The Mikoyan MiG-15 emerged from the Iron Curtain in 1950 as a total shock to the Western world. Its first assignment was in the Korean War, where it outclassed the US fighters and single-handedly caused the American F-86A Sabre to be rushed off the production line. 8,000 MiGs were built within five years as it set the template for future jet fighters.

Though a marvel of Soviet engineering, MiG-15s were powered by British Rolls Royce engines



A specialised Machine Gun Corps was created in 1915 to give the weapon a higher status in the British army

IN ACTION

THE SOMME MACHINE-GUN MASSACRE

With more than a million men killed, the 1916 Battle of the Somme is believed to be one of the bloodiest battles in human history. This was partly down to the lack of tactics to combat the new weapon of the generation, the machine gun. Unaware of the awesome power of the weapon, both sides were sitting ducks when wading through the thick mud against a wall of bullets. Reports suggested that Vickers guns alone fired in excess of a million rounds over a 12-hour period. Originally used as a defensive battlefield support weapon, the Battle of the Somme showed just how devastating machine-gun fire could be when used in an offensive capacity. With the stalemate of trench warfare ending, it was imperative that machine guns became lighter and more compact. This led to the invention of lighter machine guns and, latterly, assault rifles.

18 VICKERS MK1

DEVELOPED IN THE EARLY 20TH CENTURY, THIS MACHINE GUN WOULD REVOLUTIONISE THE WAY BATTLES WERE FOUGHT AND HOW ARMIES WERE TRAINED

It may not have been the first machine gun, but the Vickers MK 1 was essential to the rapid changes in warfare at the start of the century. Both the Gatling and Maxim guns preceded it, but its development in 1912 saw the Vickers become the most reliable and versatile machine gun of its day. By using a water-cooling jacket around the barrel, it could fire off rounds more accurately and quicker than ever before. The wall of bullets spelled the end for infantry formations and accelerated the beginning of trench warfare and no-man's land. Huge pitched battles with massive assembled infantry divisions would be no more.

Weighing in at 20 kilograms (44 pounds), the gun would be placed in a hidden position and fired on unsuspecting foes. Its bulk meant it had to be static to be effective, but in such a slow-moving conflict, this wasn't a problem.

However, it was more than just a gun – the Vickers would contain a water-condensing can and hose, a wooden sight, ammunition box and a canvas jacket. All this would be operated by a crew of up to six soldiers. Without a water supply (one batch would evaporate after 750 rounds had been fired), it would quickly overheat, so gas-powered machine guns soon became preferred.

The Vickers's counterparts in the field of battle were the German MG08 and French Hotchkiss. The gun was so popular that 12 were being made every week for the British Army and 39,473 were in use by 1918. The Vickers Company even had to lower its price to £80 per gun, so the government could finance the demand. In fact, the guns proved to be even more versatile than first thought and, armed with an interrupter gear, were attached to the fighters of the Royal Flying Corps. The fighters were now able to take on the Imperial German Air Force in ever-deadlier dogfights.

As the Great War wore on, the Vickers was slowly phased out by the Lewis gun, which boasted improved reliability and accuracy. However, the Vickers name did make a comeback with later gas-operated models lasting up to the Second World War. In fact, the British Army only considered the weapon completely obsolete in the late 1960s. The gun was an important template for later weapons, such as the MG32 and Browning, and was the first to successfully work on and improve the Maxim gun. Warfare has never been the same since.

TECHNICAL ASPECTS

COUNTRY OF ORIGIN: GREAT BRITAIN
FIRST PRODUCED: 1912
LENGTH: 58CM (38.5IN)
CALIBRE: .303IN
RATE OF FIRE: 450-550 ROUNDS PER MINUTE
FIRING RANGE: 4,100M (13,451FT)

FIRING MECHANISM

The Vickers had an operating life of around 18,000 rounds before the accuracy of the weapon began to falter. Spare barrels were carried by gun teams, as well as a tripod to keep the gun steady.

COOLANT SYSTEM

Many of the first generation of belt-fed machine guns were water-cooled. On the Vickers a jacket of water would surround the barrel to cool the mechanism and enable it to fire for longer periods of time without overheating.

OTHER USES

As well as cutting down infantry regiments, the Vickers could be tilted vertically to use as makeshift artillery. A muzzle-booster could also be fitted to the mechanism to improve the rate of fire.

MACHINE GUN LEGACY

THE VICKERS' RIVALS AND THE GUNS IT WOULD INFLUENCE

MG08

The German machine gun of choice in the First World War, the Maschinegewehr 08 was very similar to the slightly older British Maxim gun. At its peak, over 14,000 were being churned out of German factories every month and it was upgraded to an air-cooled model in 1918.

HOTCHKISS

The most cumbersome of all the WWI machine guns, the French Hotchkiss had a lower fire rate than the MG08 and Vickers. As the war went on, the French switched to using the Chauchat light machine gun as more mobile firearms became preferable.

LEWIS GUN

Used by the British in the Great War, the Lewis gun used a circular magazine rather than a belt-fed mechanism. This highly effective weapon was nicknamed the 'Belgian Rattlesnake' by the Germans and was used in unison with the Vickers. It began to phase the Vickers out as it was discovered that six could be made in the time that one Vickers could.

MG34

The MG34 was one of the most versatile of the post-Vickers guns. The Wehrmacht created the Maschinegewher 34 so it could be used on a bipod, a tripod or even without a mount. Effective and powerful, it was replaced by the MG42, which is considered once of the best machine guns of all time.

M1917 BROWNING

Perhaps the longest serving of all machine guns of the era, the M1917 was used from World War One right up until the Vietnam War. It was designed by the USA and signified their development as a military power, as before the Browning, their machine guns were very out-dated compared to the European equivalents.

Flamethrowers are unstable weapons of war, but there aren't many war machines that inspire as much terror

19 FLAMETHROWER

The turn of the 20th Century signalled the dawn of a devastating new weapon in warfare: the modern flamethrower. Yet another war machine devised to end the horrors of trench warfare, the flamethrower first saw battle on the Western Front as both sides attempted to flush out enemy trenches.

The original weapon was operated by two men and had a range of up to 40 metres (131 feet), however, they had limited usage as they only had enough oil for 40-second bursts.

Flamethrowers were later installed on tanks in the Second World War and were highly effective as a shock weapon. The armoured protection negated the weapon's lengthy reload times and a tank could store additional fuel to reload. Due to their inconsistent nature, flamethrowers have been gradually phased out of military use, but are still readily used by militant groups. These shocking weapons have encouraged the use of other incendiary weapons such as napalm and thermobaric bombs.

20 USS ENTERPRISE (CVN 65)

In 1962 a new supercarrier was born that would be the first nuclear-powered aircraft carrier ever built. Made of nearly 100,000 tons of metal, the USS Enterprise could carry over 60 aircraft and represented a new dawn for seagoing air bases.

Powered by eight reactors, it was thrust into action almost immediately, as it participated in the blockade on Cuba in the wake of the 1962 Cuban Missile Crisis. In 1965 it became the first nuclear-powered ship to engage in conflict as it entered the Vietnam War to provide support for the frontline troops. Nicknamed 'Big E', she is still the longest naval vessel in the world and has opened up a whole new era for supercarriers. The major carriers since include the entire Nimitz class of carrier and the forthcoming USS Gerald R Ford ship.

The Enterprise is a fully-functioning floating battlestation with a 1.8-hectare (4.5-acre) flight deck and a 1.4-hectare (3.5-acre) hangar

Alamy, DK Images; Corbis

21ST CENTURY COMBAT VEHICLES

The modern battlefield is a high-tech, high-stakes racefor maximum firepower

RADAR
During 2014 many Typhoons were fitted with cutting-edge Captor E sensors, which provide about 50 per cent greater coverage than traditional systems.

COCKPIT
The glass cockpit has been designed with maximum convenience for the pilot in mind. Controls are accessed via full-colour displays and some react to voice commands.

The 20th century witnessed the greatest escalation in deadly force in history. The fate of nations has rested in the hands of ingenious engineers dreaming up bigger and badder war machines.

Ever since World War I, battle tanks have played a pivotal strategic role in large-scale warfare, both during invasions and in defence of high-value ground. The main job of a tank squadron is to take out other tanks. In a fire fight, the tank with the thickest skin and the most armour-piercing firepower wins. When it comes to battlefield supremacy, the British-made Challenger 2 is a true beast.

With a battle weight of 63 tons (139,000 pounds), the Challenger 2 is surprisingly nimble, reaching top road speeds of 59 kilometres (37 miles) per hour. But its real talent is blowing stuff up. One blast from the Challenger 2's 120-millimetre (4.7-inch) main gun will level a lesser tank, while its own crew is protected by next-generation armour. The explosive reactive tiles built into its front and flanks respond to a rocket-launched grenade attack by repelling enemy rounds in the opposite direction.

Tanks are excellent at holding ground in a warzone, but if you want a truly versatile fighting machine, nothing beats an attack helicopter. The current chopper of choice for the US Marines is the AH-1Z Viper, codenamed 'Zulu'. The four-bladed Viper reaches top air speeds of 410 kilometres (255 miles) per hour, perfect for rocketing behind enemy lines for a late-night rescue mission. And its firepower – including Hellfire air-to-ground missiles – provides critical close-air support for a ground invasion.

The Viper isn't all strength and speed though; it's also smart. Using a host of sensors and radar equipment, the onboard computers can distinguish between friend and foe, target and track multiple guided missiles, as well as transmit air reconnaissance data to ground troops. Even the Viper's pilot helmets are smart, featuring heads-up displays in the visors that overlay flight routes and enemy targets directly onto the landscape below.

While the Zulu may be a new kid on the block, even more senior attack helicopters can be

"THE FATE OF NATIONS OFTEN RESTS IN THE HANDS OF INGENIOUS ENGINEERS DREAMING UP BIGGER AND BADDER WAR MACHINES"

COUNTERMEASURES
The Typhoon's Defensive Aids Sub System (DASS) boasts numerous flares and decoys to throw off incoming missiles.

WEAPONS
As well as a 27mm (1in) Mauser cannon and short-range missiles, the arsenal of this fighter jet includes some of the deadliest weapons around, such as the ramjet-propelled Meteor missile.

POWERPLANT
The twin EJ200 turbofans are 74cm (29in) in diameter and each provide 90kN of thrust. Offering a top speed of Mach 2, the same jet engine is used to power the Bloodhound SSC supersonic car.

AIRFRAME
The shell of the Eurofighter Typhoon is made with composite materials that aim for strength, lightness and stealth. 70 per cent of the structure is made from blends of carbon fibre and only 15 per cent comprised of metal.

The Eurofighter Typhoon is one of the most advanced aircraft ever built, but it doesn't come cheap at £126 million per plane

taught new tricks, as demonstrated by the latest reincarnation of the Apache (see page 26). But for all the power of tanks and speed of helicopters, the ultimate modern war machine has to be the fighter jet. Dominance in the air generally translates into dominance on the ground. Radar-eluding jets can penetrate deep into enemy territory and fire laser-guided missiles to destroy a target in seconds. One of the most advanced models in service is the Eurofighter Typhoon.

At a cost of £126 million ($208 million) per plane, the Typhoon is designed to be an all-in-one soldier of the skies. It can perform reconnaissance with its scanning radar, take out enemy aircraft in a close-range dogfight and drop heavy payload bombs on long-range targets – all on the same mission. The Typhoon is only 15 per cent metal, making it all but invisible to radar, and its intentionally 'unstable' delta-wing design provides maximum agility at subsonic speeds and peak performance during supersonic flight.

Of course, the war machines of the future may not even need people on board to operate them. Unmanned drones have already proven deadly accurate in locating and destroying key enemy targets. An MQ-9 Reaper drone can deliver laser-guided missiles and air-to-ground Hellfire missiles, all with the push of a button far away. It's not hard to imagine tomorrow's battles being played out by swarms of remote-controlled war bots.

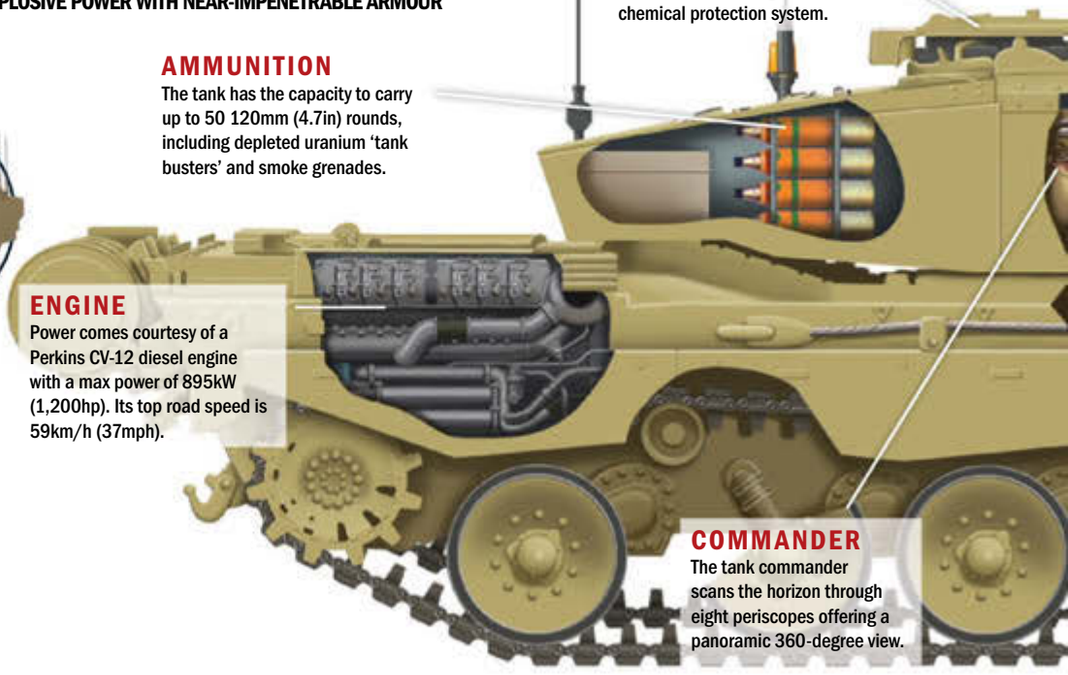
The Challenger 2's Chobham armour is reported to be twice as strong as steel

WAR MACHINES GOING GREEN

The BAE Ground Combat Vehicle (GCV) is the Prius of the tank world. Powered by a hybrid-electric propulsion system, the GCV offers the US Army more than savings at the petrol pump. The lightweight engine frees up weight that can be added to the tank's armour. Energy stored in the propulsion system allows for maximum power at startup. The hybrid engine also produces 1,100 kilowatts of exportable electricity – enough to power the advanced onboard computers and portable battle gadgets. Less fuel consumption also means fewer supply lines, which are a frequent target for roadside bomb attacks.

UP CLOSE WITH THE CHALLENGER 2

THE BRITISH ARMY'S MAIN BATTLE TANK COMBINES EXPLOSIVE POWER WITH NEAR-IMPENETRABLE ARMOUR



TURRET

The Challenger 2's turret rotates a full 360 degrees and is equipped with a nuclear, biological and chemical protection system.

AMMUNITION

The tank has the capacity to carry up to 50 120mm (4.7in) rounds, including depleted uranium 'tank busters' and smoke grenades.

ENGINE

Power comes courtesy of a Perkins CV-12 diesel engine with a max power of 895kW (1,200hp). Its top road speed is 59km/h (37mph).

COMMANDER

The tank commander scans the horizon through eight periscopes offering a panoramic 360-degree view.

The French 56-ton AMX Leclerc is one of the biggest tanks in the world

The Russian T-90A tank boasts a welded turret and an ESSA thermal imaging viewer for night missions

WHAT IS IT LIKE TO WORK INSIDE A BATTLE TANK?

TANK DRIVING INSTRUCTOR SGT ARRON ANDERTON TELLS US ALL ABOUT THE EXPERIENCE OF OPERATING A CHALLENGER 2

WHAT DOES IT FEEL LIKE TO DRIVE THE CHALLENGER 2?

SGT ARRON ANDERTON: The Challenger 2 is a complex piece of equipment but once trained it is not that difficult to drive. It can take some time to get used to its size when you first start driving it, [but] once you gain more experience it can become quite fun to drive. The Challenger 2 has exceptional cross-country capability but due to the driver's restricted vision they need to read the ground up to 50 metres [164 feet] away so they can make adjustments to the direction and speed. The Challenger 2 is quite easy to handle at high speeds but is more difficult to negotiate around tight corners. The tank is [manoeuvred] by two steering levers located on either side of the driver.

WHAT IS THE HARDEST PART OF DRIVING A CHALLENGER 2?

AA: The hardest part of driving the Challenger 2 is judging the size of the vehicle's width on public roads and driving it in confined spaces. The driving position is located in the centre of the vehicle which is different to standard cars and lorries and does take some time to get used to.

HOW DOES IT FEEL IN THE TANK DURING A FIREFIGHT?

AA: When you are sat inside a Challenger 2 during 'live' firing of the weapons systems you tend to become oblivious to the firing of the chain gun or the bang from the 120mm [4.7in] main armament gun. The vehicle does shake a little but this adds to the adrenaline when you're scanning for targets and ensuring you engage the targets in time. Coming under small-arms (ie rifles and machine guns) fire can sound like hailstones on a tin roof, it does give you a sense of invulnerability!

TELL US ABOUT THE ROLES OF EACH OF THE CREW MEMBERS

AA: The Challenger 2 has a four-man crew: a driver, gunner, loader (and radio operator) and commander. The driver steers the vehicle and carries out all the daily and major maintenance and running repairs. He also assists the REME (vehicle mechanics) with major repairs.

The gunner maintains the weapons systems and engages the targets identified by the commander and the crew. The loader loads the main armament and the 7.62mm [0.3in] chain gun. They have secondary duties of assisting the commander with operating the radio. The commander is in overall [charge] of the vehicle and all crew members. They navigate, send and receive radio messages and prioritise targets to be engaged by the gunner.

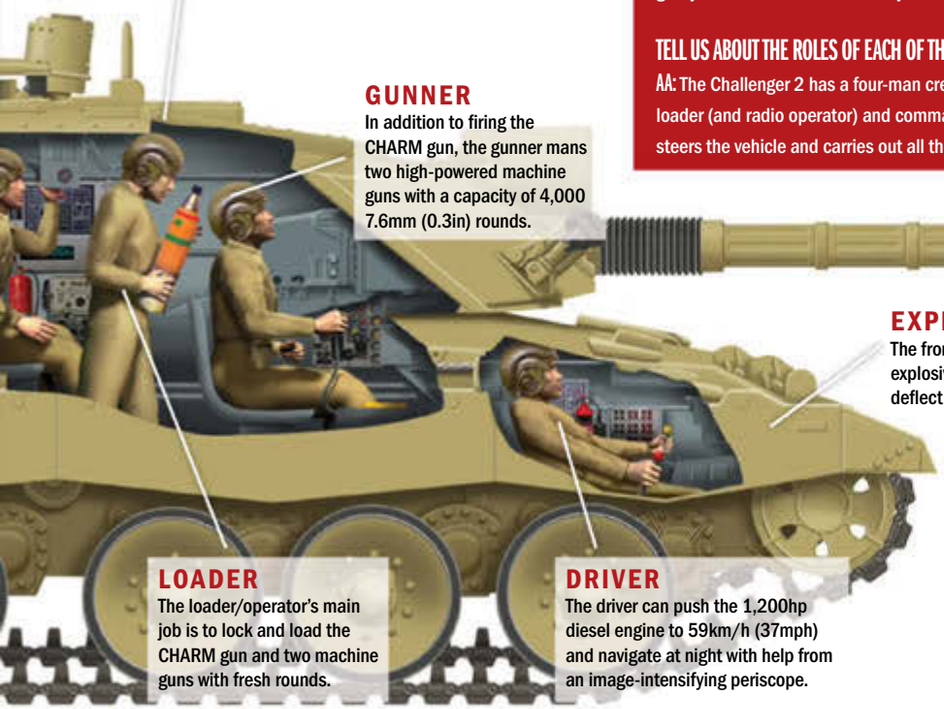
Due to working and living in a confined space, the camaraderie has to be second to none. As you can imagine working, living, eating, sleeping in a confined space for extended periods presents some problems – the smell can be eye-watering!

WHAT EQUIPMENT DOES THE CREW RELY ON TO NAVIGATE?

AA: Combat navigation is fitted to the vehicle and personal GPS. Additionally, good old-fashioned maps still form an integral part of navigation around the battlefield; the commander needs to be a navigational expert.

WHAT ROLES DO TANKS ASSUME IN A WARZONE?

AA: A tank is a highly sophisticated fighting machine. It has the characteristics of firepower, protection, mobility and sustainability – it is also designed to operate in a CBRN [chemical, biological, radiological and nuclear] environment. It is used in all phases of battle (the advance to contact, the attack, the defence and withdrawal). It will invariably operate in an all arms environment, ie with infantry, artillery and air support. Due to its night-vision ability it can fight a 24-hour battle. Although it will normally operate in open spaces it can, with intimate infantry support, operate in built-up areas. For example, in recent years it proved highly successful in the Iraq conflict.



THICK SKIN
The turret is shielded from enemy fire by Chobham armour, a composite of metal plates and ceramic tiles separated by air.

GUNNER
In addition to firing the CHARM gun, the gunner mans two high-powered machine guns with a capacity of 4,000 7.6mm (0.3in) rounds.

EXPLODING ARMOUR
The front and sides are covered with explosive plates that ignite on contact to deflect the force of enemy rounds.

L30 CHARM GUN
Challenger 2's main weapon fires 120mm (4.7in) projectiles including armour-piercing, high-explosive squash head (HESH) rounds.

LOADER
The loader/operator's main job is to lock and load the CHARM gun and two machine guns with fresh rounds.

DRIVER
The driver can push the 1,200hp diesel engine to 59km/h (37mph) and navigate at night with help from an image-intensifying periscope.

HOW LONG DOES IT TAKE TO TRAIN THE CHALLENGER 2 CREW MEMBERS?


DRIVER 6 WEEKS


LOADER 2 WEEKS


GUNNER 6 WEEKS


COMMANDER 5 MONTHS

ENGINEERING OF THE AH-1Z VIPER

WHAT MAKES THE ZULU HELICOPTER AMONG THE MOST ADVANCED VEHICLES ON EARTH TODAY?

HELMET
State-of-the-art 'Top Owl' helmet-mounted sight and display (HMS/D) units offer a binocular display with a 40-degree field of view and easier comms.

AVIONICS
A third-gen forward-looking infrared (FLIR) sensor offers one of the most accurate weapons sights on any modern helicopter whether day, night or in adverse weather. It can track multiple out-of-sight targets simultaneously.

ENGINES
Combined with the main rotor system, the two T700-GE-401 engines power the AH-1Z, giving it a cruise speed of just under 300km/h (186mph).

ROTOR BLADES
The four blades are made of composite materials which can better withstand bullets. They can also be folded to better fit on aircraft carriers.

WING STUBS
Although not needed for flight, these mini-wings offer valuable space for mounting weapons and radar tech.

MAX SPEED
The tank can hit 59km/h (37mph) on roads.

POWER
1,200bhp Perkins-Condor CV12.

MAX SPEED
During a dive the Zulu can reach 411km/h (255mph).

POWER
Two T700-GE-401 turboshaft engines.

POWER
A pair of EJ200 turbojet engines.

CHALLENGER 2
- CREW: 4
- ARMOUR: 5/5
- COST: £4MN ($6.6MN)

BELL AH-1Z ZULU
- CREW: 2
- ARMOUR: 2/5
- COST: £18.8MN ($31MN)

EUROFIGHTER TYPHOON
- CREW: 1
- ARMOUR: 1/5
- COST: £126MN ($208MN)

"FIGHTER JETS ARE HUGELY IMPORTANT – DOMINANCE IN THE AIR TRANSLATES TO DOMINANCE ON THE GROUND"

WEAPONRY
120mm L30 tank gun, C-axial 7.62mm chain gun, 7.62mm turret-mounted machine gun.

MAX FIRING RANGE
HESH rounds fired from the Challenger 2 can travel 8km (5mi).

WEAPONRY
Hellfire air-to-surface missiles, Sidewinder air-to-air missiles and unguided Hydra 70 rockets.

MAX FIRING RANGE
Sidewinder missiles can reach a target up to 35km (22mi) away.

MAX FIRING RANGE
The new Meteor missile has a range in excess of 100km (68mi).

WEAPONRY
Long and short-range air-to-air missiles, 27mm Mauser cannon and laser-guided bombs.

MAX SPEED
The Typhoon's record speed is Mach 2 (2,470km/h; 1,535mph).

NEXT-GEN WEAPONS


Laser-based weapons are already being fitted to today's combat vehicles

The Challenger 2's main gun is essentially a bigger version of the same rifled-cannon tech that has been blasting oversized rounds for nearly a century. The weapons of the future are more subtle, but immensely more strategic. Take the Passive Attack Weapon developed by the Pentagon to safely eradicate stores of deadly bioagents. Dropped from the above, the 450-kilogram (990-pound) bomb explodes in mid-air, raining down thousands of steel and tungsten rods that can penetrate chemical weapon canisters.

Microwave bombs made for the US Air Force disable the electrical systems of target buildings with a fuse-frying pulse of radio waves. The US Navy has been testing 32-megajoule rail guns that use magnetic fields to launch armour-piercing projectiles 185 kilometres (115 miles) without gunpowder. And what would the future of weapons be without lasers? The US Navy is testing its solid-state Free Electron Laser with hopes of creating a weapon capable of melting through 610 metres (2,000 feet) of steel per second!

READY FOR BATTLE!

1 HMS AMBUSH

The Royal Navy's newest nuclear submarine boasts sonar sensitive enough to detect craft about 5,630km (3,500mi) away. Built for over £1bn ($1.6bn), the Ambush carries a payload of 38 Tomahawk cruise missiles.

2 B-2 SPIRIT
The iconic batwing stealth aircraft is the USAF's flagship strike bomber. Able to fly 18,520km (11,508mi) with just a single aerial refuelling, it can deliver over 20 tons of bombs deep into enemy territory.

3 USS ZUMWALT
This 'all-electric' US Navy destroyer generates all the power it needs. The ship's sharp-angled hull lowers its radar profile and its payload includes two 155mm (6.1in) guns capable of striking a target 154km (96mi) away.

4 ASSAULT BREACHER VEHICLE

The US Army's mine-clearing tank's signature move is firing a rocket that unfurls 100m (328ft) of sausage-like tubing packed with a ton of C4 explosives, clearing an area the size of a football pitch of hidden mines.

5 ATF DINGO

A German armoured mobility vehicle used to transport troops, the Dingo is reinforced to withstand land mines, gunfire and many other heavy weapons. The top-mounted weapons station can be fired by a gunner directly, or via remote control using a monitor inside the cabin.

EVOLUTION OF THE APACHE

The AH-1Z Zulu might be newer, but there is arguably another attack helicopter more renowned for its deadliness: the AH-64 Apache. A barbarous hybrid of power, penetration and liquid speed, the Apache excels in ravaging enemy lines and installations, laying waste to the strongest of battlements with high-explosive missiles and rockets, while gunning down any attackers with its 30-millimetre (1.2-inch) chain gun. As history has shown, with the Apache successfully deployed in the Gulf, Balkan, Iraq and Afghanistan conflicts among many others, these abilities have been proven time and again, with its 14-plus operators worldwide using it in all manner of roles.

Interestingly though, despite the Apache's mighty arsenal of offensive weapons, the real reason it is such a feared opponent on the battlefield is the advanced nature of its combat systems and electronics. For example, its avionic and sensor suite includes a target acquisition and designation system (TADS), pilot night-vision system (PNVS), GPS navigation, passive infrared countermeasure system, ground-fire acquisition system (GFAS) and, most cutting-edge of all, an integrated helmet and display sighting system (IHADSS). A bit like a military take on Google Glass, this latter piece of technology augments the pilots' control in a number of ways (see 'Apache anatomy' for more). Combined these technologies enable this incredible helicopter to operate in the harshest environments with ease, while always ensuring it hits its target.

The Apache's resilience in combat has also made it one of the foremost war machines of the age, with the helicopter made to demanding build and crashworthiness standards. Indeed, during the Gulf War many Apaches were repeatedly hit by small-arms fire and rocket-propelled grenades, but only one of them went down and even then both of its pilots survived. Similarly and more recently in Afghanistan, many Apaches were hit in Operation Anaconda (2002), but ultimately none were brought down by the enemy, with the helicopter's toughened airframe, along with features such as a self-sealing fuel system, managing to see off all incoming fire.

Maybe the most telling aspect to the Apache's prowess on the battlefield, however, is its enduring legacy – one which is still playing out, even after 28 years of fighting on the frontline. Indeed, this technical leader of attack helicopters continues to be improved all the time, with additional operators such as India, South Korea and Indonesia looking to take up the Apache in the near future. Additional technological enhancements, such as an upgraded transmission with split-torque face gears for more power output and an improved all-digital communications system look set to keep this helicopter at the top of its class for some time yet.

APACHE ANATOMY

GET UP CLOSE AND PERSONAL WITH THE TECH OF THIS EVER-EVOLVING FRONTLINE VETERAN

The USA currently operates 669 Apache attack helicopters, with that number set to rise over the next decade

ROTOR BLADES

The Apache has a four-blade main rotor and a four-blade tail rotor, which grant a maximum rate of climb of 889m (2,915ft) per minute. It also boasts superb manoeuvrability for a helicopter, easily capable of complex, low-altitude operations.

MISSILES

The arsenal carried by the Apache is devastating, with missiles such as the AGM-114 Hellfire and AIM-92 Stinger partnered with a bounty of 70mm (2.8in) Hydra 70 rockets and the ever-reliable 30mm (1.2in) M230 chain gun with 1,200 rounds.

POWERPLANT

The Apache is powered by two GE T700 turboshaft engines, each with high-mounted exhausts on either side of the fuselage. This powerplant grants a top speed of 293km/h (182mph).

HUMAN-MACHINE INTERFACE

The integrated helmet and display sighting system (IHADSS) allows advanced features such as syncing the helicopter's M230 chain gun with the pilot's head movements, so the guncan be aimed with the turn of the head.

CONTROLS

With laser, infrared and thermal tracking systems, including a target acquisition night-vision sensor, as well as a threat prioritisation system, the Apache is ideal for covert and low-visibility operations.

TANDEM CONTROL

The crew of the Apache sits in tandem, with one pilot sitting above and behind the other. Both pilots can fly the gunship and both can operate all weapons systems – critical when fighting in today's complex warzones.

STRYKER IN FOCUS

CHECK OUT SOME OF THE KEY FEATURES PACKED INTO THESE TOP-RATE AFVS

DIESEL ENGINE
A heavy-duty 261kW (350hp) Caterpillar JP-8 diesel engine grants the Stryker its mobile power, allowing the 16-ton vehicle to surpass 97km/h (60mph) with ease.

MACHINE GUN
A .50-calibre machine gun that can be manned or controlled from within the Stryker proves a lethal tool against infantry and light armoured vehicles.

ELECTRONICS
The Stryker comes with a Force XXI Battle Command Brigade and Below (FBCB2) digital comms system that allows communication between vehicles and a remote weapons system (pictured) to fire from the safety of the cabin.

ROOM TO SPARE
Along with a two-man crew, the Stryker can carry up to nine fully equipped soldiers in its rear compartment, plus a wide selection of vital equipment and provisions.

TOUGH SHELL
The Stryker is built around a toughened steel skeleton and has a spall liner. 14.5mm (0.6in)-thick armour plate kits can be fitted to its chassis for even more protection.

ALL-WHEEL DRIVE
Depending on terrain, thanks to the Stryker's advanced Allison transmission, the driver can switch between four and eight-wheel drive operation modes.

The Stryker boasts an unmatched combination of survivability, mobility and lethality

ARMOURED FIGHTERS ON WHEELS

Sure, if you want the heaviest armour or most destructive firepower on the battlefield, then you call in a tank. But tanks tend to be decidedly one note in the theatre of war and cumbersome when posed with any obstacle outside their immediate remit – ie blowing things into last week with a massive cannon! As a result, today national militaries are calling upon a different class of war machine more and more. The armoured fighting vehicle (AFV) is an impressive combo of personnel carrier, tank and military jeep which can undertake almost any mission due to its unparalleled flexibility.

While a tank is great at crossing rough terrain with its caterpillar track, that system's inherent limitations along with the machine's gross weight restrict its agility and speed massively. Examples like the Challenger 2 struggle to get past 60 kilometres (37 miles) per hour and possess next to no agility. On the other hand, the armoured fighting vehicle delivers a shielded vehicle that easily blows through 100 kilometres (60 miles) per hour, is capable of traversing cross-country terrain with ease, can sport a wide variety of cannons, machine guns and missiles, and is able to transport nine fully equipped soldiers on top of that – all without so much as breaking a sweat.

Of this new wave of vehicles, the Stryker family of AFVs made by General Dynamics Land Systems is one of the most advanced and prolific. The wide range of formats the Stryker comes in really highlights why they are not only usurping more and more of the roles historically assigned to tanks but executing them far more effectively.

For example, the Stryker family members include vehicles equipped for anti-tank operations, medical evacuation missions, fire support and reconnaissance, infantry deployments and direct-fire assaults, to name just a few! Strykers offer these bespoke abilities with an agility, speed and cost-effectiveness unheard of in the tank world. You might start to wonder if the armoured fighting vehicle will make the tank obsolete, but this is unlikely. Sometimes only the biggest and heaviest armoured machine is capable of breaking down an enemy's front door, but moving forward into the 21st century, there's no doubt the use of multipurpose vehicles like the Stryker will rise. In almost every arena, speed and adaptability can be the difference between success and failure. Nowhere is that more true than in modern warfare, and the still-evolving armoured fighting vehicle delivers both with consummate ease.

AWESOME AMPHIBIANS

With flexibility being key to success in the realm of modern combat, one vehicle firmly on the up is the amphibious assault vehicle – essentially an armoured personnel carrier and landing boat hybrid. They enable troops to be deployed remotely from the ocean, transported under bulletproof protection to shore and then distributed over enemy terrain, without any slow and dangerously exposed vehicle changes, quickly getting soldiers to where they need to be.

Arguably the most successful amphibious assault vehicle in production today is the AAV-P7/A1, a tracked amphibious landing vehicle produced by US Combat Systems (now part of BAE Systems). It delivers a 26-ton armoured personnel carrier with 45-millimetre (1.8-inch) armour plating, a roof-mounted Mk 19 automatic grenade launcher, a .50-calibre machine gun and room for 21 soldiers in its cavernous rear compartment. Perhaps most impressive though, the AAV-P7/A1 can cruise up to 37 kilometres (23 miles) through choppy waters before hitting land and still has enough steam to operate for some 480 kilometres (300 miles) on terra firma.

LAND

ANATOMY OF THE SCOUT SV

74 Find out which features make the scout revolutionary

© General Dynamics

TIGER I

46 Inside the Wehrmacht's fearsome WWII tank

LIGHT TANKS

30 Compare historic models from armed forces around the world

© Corbis

© AM General

70 Get on board the ubiquitous troop transport **HUMVEE**

INVISIBILITY TECH

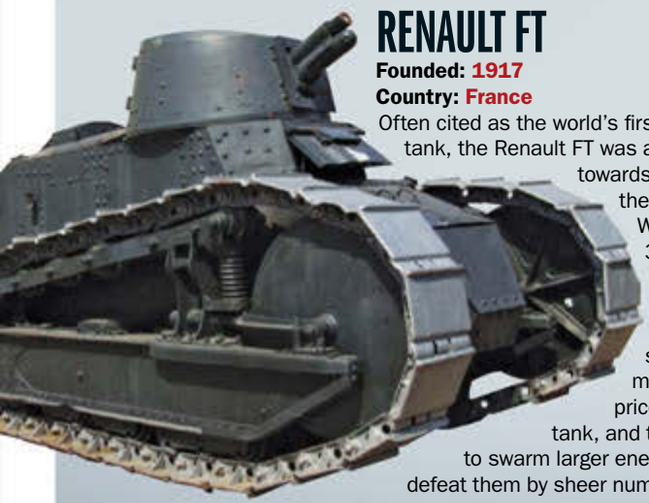
74 Discover the adaptive system behind the tanks of tomorrow

WILLYS JEEP

68 Get behind the wheel of one of the most iconic vehicles ever

LIGHT TANKS

Light tanks first saw action in WWI and demonstrated their versatility throughout the 20th Century, before arguably becoming obsolete



RENAULT FT

Founded: 1917
Country: France

Often cited as the world's first 'modern' tank, the Renault FT was a stalwart towards the end of the First World Wad, with over 3,000 of them produced during that time. Five or six could be made for the price of a larger tank, and they were built to swarm larger enemies and defeat them by sheer numbers.

T-26

Founded: 1931
Country: Soviet Union

The Soviet T-26 was heavily based on the Vickers Mark-E light tank operated by the British, and became an admirable model for rapid production. It's quite remarkable that over 10,000 of these machines were operational by 1939, cementing the Soviet Union's reputation as a military industrial powerhouse.

M3 STUART

Founded: 1940
Country: USA

The M3 is certainly one of the most well-known light tanks ever built, and was produced in large numbers by the US during the war. Many of these Stuarts would be leased to Commonwealth forces, and a large number of them saw action in North Africa against Rommel's fearsome Afrika Korps.

M551 SHERIDAN

Founded: 1966
Country: USA

Built to replace the heavy M41 Walker Bulldog, the Sheridan tank was used extensively during the Vietnam War as a reconnaissance and light infantry support vehicle. This was despite its weak hull armour and subsequent vulnerability when faced with RPG fire or AT mines.

TYPE 95 HA-GO

Founded: 1936
Country: Japan

Due to the demand for faster and more-reliable armour, the Japanese brought this light tank into production a few years before the outbreak of WWII. Its Hotchkiss-inspired cannon was built for dispensing with infantry, and two Type 97 LMGs completed the arsenal.

FV-101 SCORPION

Founded: 1972
Country: United Kingdom

Some Scorpions are believed to still be in use today around the world, with half of those produced being allocated for export. Only weighing eight tons, the Scorpion was an ideal vehicle for infantry support and reconnaissance, seeing action in the First Gulf War as well as the Falkland Islands conflict in 1982.

TYPE 62

Founded: 1962
Country: China

The Type 62 was built with manoeuvrability in mind, as well as economy. Due to its low cost it was adopted by certain African nations for use domestically, and the overall design was derived from the Soviet T-54. It first saw action in Vietnam after the Chinese provided several of the units to the NVA prior to the invasion of Kampuchea.

5 Facts about LIGHT TANKS

DROPPED ON PANAMA

The American M551 Sheridan was actually capable of being air-dropped from a cargo plane, with this being achieved for the first time during the US invasion of Panama.

EQUAL OPPORTUNITIES

The French Renault FT was available in both male and female varieties. The more common female carried a mounted machine gun, while the male sported a short-barrelled 37mm gun.

THE MAE WEST TANK

During the Thirties, American troops nicknamed some of the early dual-turreted light tanks 'Mae West', as an homage to the decidedly busty movie star of the time.

A STRANGE EXPERIMENT

In 1942, the Soviet Union tested, somewhat successfully, a flying light tank. The A-40 was attached to a pair of wings that allowed it to be towed in mid air and then released onto the battlefield.

THE RECORD-BREAKER

The British Scorpion Peacekeeper tank was recognised by Guinness World Records as the fastest tank ever created, achieving an incredible 51mph on a test track in 2002.

Alamy; Corbis

HEAD TO HEAD

War rages on the Eastern Front as the old Wehrmacht war horse, the Panzer I, goes up against the new kid on the block, the Soviet T-70

T-70

YEARS IN OPERATION: ***1942-1948***
LOYALTY: ***USSR*** *NUMBER MADE:* ***8,200***

FIREPOWER

Surprisingly heavy for a light tank, the T-70 had a 45mm gun that used both armour-piercing and explosive rounds. Its secondary weapon was a 7.622mm machine gun.

SPEED

The T-70 had 140 horsepower at its disposal, which gave it a top speed of 45km/h (28mph). Light tanks had to be quick to compensate for their thin armour.

TACTICS

With a crew of two, the T-70 struggled to use its main turret effectively and became more of a reconnaissance vehicle. Its chassis would later be used for SU-76M tank killers and the T-80.

RANGE

A fuel capacity of 120 US Gallons gave the T–70 a range of 360km (224 miles) and helped it zoom across the Eastern Front, where it regularly supported the medium T-34 tank in battle.

ARMOUR

Protection began at 35mm, but increased to 45mm in later models. The armour was reasonable, but wasn't enough to shield the T-70 from larger tanks and artillery on the battlefield.

LEGACY

It may have been the most produced Soviet light tank of the war but the T-70 quickly became obsolete and was quickly changed to an anti-tank vehicle to suit its qualities.

TOTAL

SOVIET TANK PRODUCTION

Churning out T-70s like there was no tomorrow, the Soviet production line was bolstered by the decision to turn civilian factories into military production centres. The T-70 itself was often partnered with the T-34 on the battlefield as they fought the Germans at huge battles such as Kursk. Before the end of the war it was effectively replaced by the T-80, and its chassis was used on tank destroyers like the SU-76M and anti-aircraft guns such as the ZSU-37 as battlefield tactics and technology began to veer away from lighter tanks towards heavier, stronger models.

While the Germans where focusing on quality, the Soviets went for sheer numbers. The tactic worked, as the Wehrmacht was overwhelmed

PANZER I

YEARS IN OPERATION: 1935-1945
LOYALTY: NAZI GERMANY *NUMBER MADE:* 2,800

FIREPOWER

The Panzer I lacked a main gun, instead employing two 7.92mm MG-13 machine guns that could fire 650 rounds per minute and had 2,250 rounds of ammunition.

SPEED

Being an older tank, the Panzer could only muster 49km/h (25mph), but in the early days of the war that was more than enough to operate as an effective troop support.

TACTICS

The Panzer I was incredibly effective in the opening exchanges of the war as it stormed out of Germany as one of the main components of 'Blitzkrieg'.

RANGE

The Panzer could traverse 140 kilometres (87 miles) without filling up, which proved to be more than enough for rapid assaults of 'lightning war'.

ARMOUR

The steel plated armour of a Panzer I was some of the most primitive in the German armoured division, only a mere 12.5mm in thickness.

LEGACY

Even though light tanks were superseded by heavier models in the Wehrmacht, the Panzer I was the starting point for German tank production and showed their intent on rearmament.

TOTAL

The German tank production line was efficient, but could not match the output of the allied powers

GERMAN TANK PRODUCTION

Throughout World War I, Germany had seemingly very little interest in tanks, but this changed dramatically in the vast rearmament of the Thirties. The first tank to appear on the Wehrmacht production line and breach Versailles was the Panzerkampfwagen I. The first of many, the model was used extensively on both the Western and Eastern Fronts and became a major element of blitzkrieg. As time wore on, the Third Reich changed their focus from light tanks to medium and heavy Panzers such as the Tiger and Panther, but the legacy of the Panzer I lived on.

"THE PANZER I WAS INCREDIBLY EFFECTIVE IN THE OPENING EXCHANGES OF THE WAR AS IT STORMED OUT OF GERMANY AS ONE OF THE MAIN COMPONENTS OF BLITZKRIEG"

LIGHT TANKS OF THE WORLD

Stretching track marks across the globe and throughout the 20th Century

1 SIEGE OF TOBRUK

TOBRUK, LIBYA 10 APRIL 1941

Large numbers of light tanks from the British Commonwealth go into fierce battles with Rommel's armoured Afrika Korps to protect the Allied toehold in Eygpt.

Britain's General Bernard L Montgomery in North Africa.

Vickers 6-ton

Landsverk L-120

Operating: 1937
Speciality: Defence and infantry support
Location: Sweden

Vickers 6-ton

Operating: 1929
Speciality: Long-range cross-country manoeuvres
Location: United Kingdom

T15

Operating: 1936
Speciality: High-speed off-road manoeuvres
Location: Belgium

Hotchkiss H35

Operating: 1935
Speciality: Engaging other light tanks
Location: France

Verdeja 1

Operating: 1940
Speciality: Infantry support and assault
Location: Spain

SK-105 Kürassier

Operating: 1967
Speciality: Anti-tank operations
Location: Austria

US LIGHT TANKS

M2 Light Tank

Operating: 1935
Speciality: Anti-infantry operations

M41 Walker Bulldog

Operating: 1953
Speciality: Scouting and infantry support

M22 Locust

Operating: 1942
Speciality: Airborne support and recon

M22 Locust

TAM

Operating: 1976
Speciality: Infantry combat and wading
Location: Argentina

Argentine TAM

2 D-DAY

NORMANDY, FRANCE 6 JUNE 1944

The Normandy landings of Operation Overlord required the Allies to deposit a large amount of armour onto French shores. Among these were British and American light tanks, along with the near ubiquitous Sherman.

A Free French Sherman medium tank rolls onto Utah Beach in 1944

3 FIRST BATTLE OF NAKTONG BULGE

SOUTH KOREA 6 AUGUST 1950

North Korea crosses the Naktong River and into US-held South Korean territory. The Americans are on stand-by with M24 Chaffee light tanks, which saw service until after Vietnam.

The Soviet offensive at Kursk put the Germans on the back foot

RUSSIAN LIGHT TANKS

PT-76
Operating: 1951
Speciality: Recon and troop support

T-18
Operating: 1928
Speciality: Strength and firepower

Russian T–18

5 BATTLE OF STALINGRAD

STALINGRAD, RUSSIA 2 FEBRUARY 1943

The German army surrenders at Stalingrad following a fierce counter-attack from the Soviet Union and its bevy of light tanks. Many cite this defeat as the turning point of the war on the Russian Front.

6 BATTLE OF KURSK

KURSK, RUSSIA 5 JULY 1943

Georgiy Zhukov, springs his armoured trap on the Axis. American M3 tanks are utilised by the Soviet Union during some of the fiercest tank fighting ever known, although they prove unpopular.

M1985
Operating: 1985
Speciality: Amphibious reconnaissance and assault
Location: North Korea

French AMX-13

7 THE BURMA FRONT

BURMA 20 FEBRUARY 1942

The 7th Armoured Division, famously christened the Desert Rats, reaches Rangoon in Burma with light tanks and cruisers in order to set up defences in an attempt to halt the Japanese invasion of mainland Asia.

8 SIX DAY WAR

SINAI PENINSULA, EGYPT 5 JUNE 1967

Israel and a conglomerate of Arab territories go toe to toe in the Six Day War, each utilising a host of different light tank designs including AMX-13s and Soviet PT-76s.

Type 63A
Operating: 1997
Speciality: Long-range amphibious assaults
Location: China

Type 63A

British Crusader tanks move into position in North Africa

4 SECOND BATTLE OF EL ALAMEIN

EL ALAMEIN, EGYPT 23 OCTOBER 1942

German Panzer II tanks face off against a cohort of Crusader Mk I tanks of Great Britain as Monty goes head-to-head with Rommel.

ANATOMY OF A...
PANZER II

Developed clandestinely before the invasion of Poland, the Panzer II was phased out from 1942 though its chassis was used on a number of self-propelled guns until 1944

7.92MM COAXIAL MASCHINENGEWEHR
Also known by the designation MG 34, the 7.92 machine gun fitted to the Panzer II was an effective anti-infantry weapon and also saw service as a support weapon among Wehrmacht platoons.

HATCH FOR ENTRY OR ESCAPE

20MM MAIN GUN
Produced in Germany in the mid-to-late Thirties, the 2cm KwK 30 L/55 was based on a 20mm flak cannon and was fully automatic, requiring the operator to fire in controlled bursts.

THE TRACKS

THE FRONTAL GLACIS
These only sported the standard amount of armour, which was strange for a tank, but later received a new single piece 30mm glacis upon reaching its final Ausf F designation.

MANUAL TRANSMISSION SYSTEM
The Panzer II sported a six-speed plus reverse manual gearbox made by ZF Friedrichshafen, which was generally considered to be reliable. Reversing was particularly handy for these little tanks.

PANZERKAMPFWAGEN II

YEARS IN USE: 9
COUNTRY OF ORIGIN: GERMANY
ENGINE SIZE: 6-CYLINDER, 138HP
CREW: 3
LENGTH: 4.81M
WEIGHT: 8.9 TONS
TOP SPEED: 25MPH
WEAPONS: 1 X 20MM KWK 30 MAIN GUN, 1 X 7.92MM COAXIAL MACHINE GUN

HAND-CRANKED TURRET

The turret on the Panzer II was actually operated by the tank's commander rather than a specific gunner, as the limited space inside the machine only allowed for three crew members.

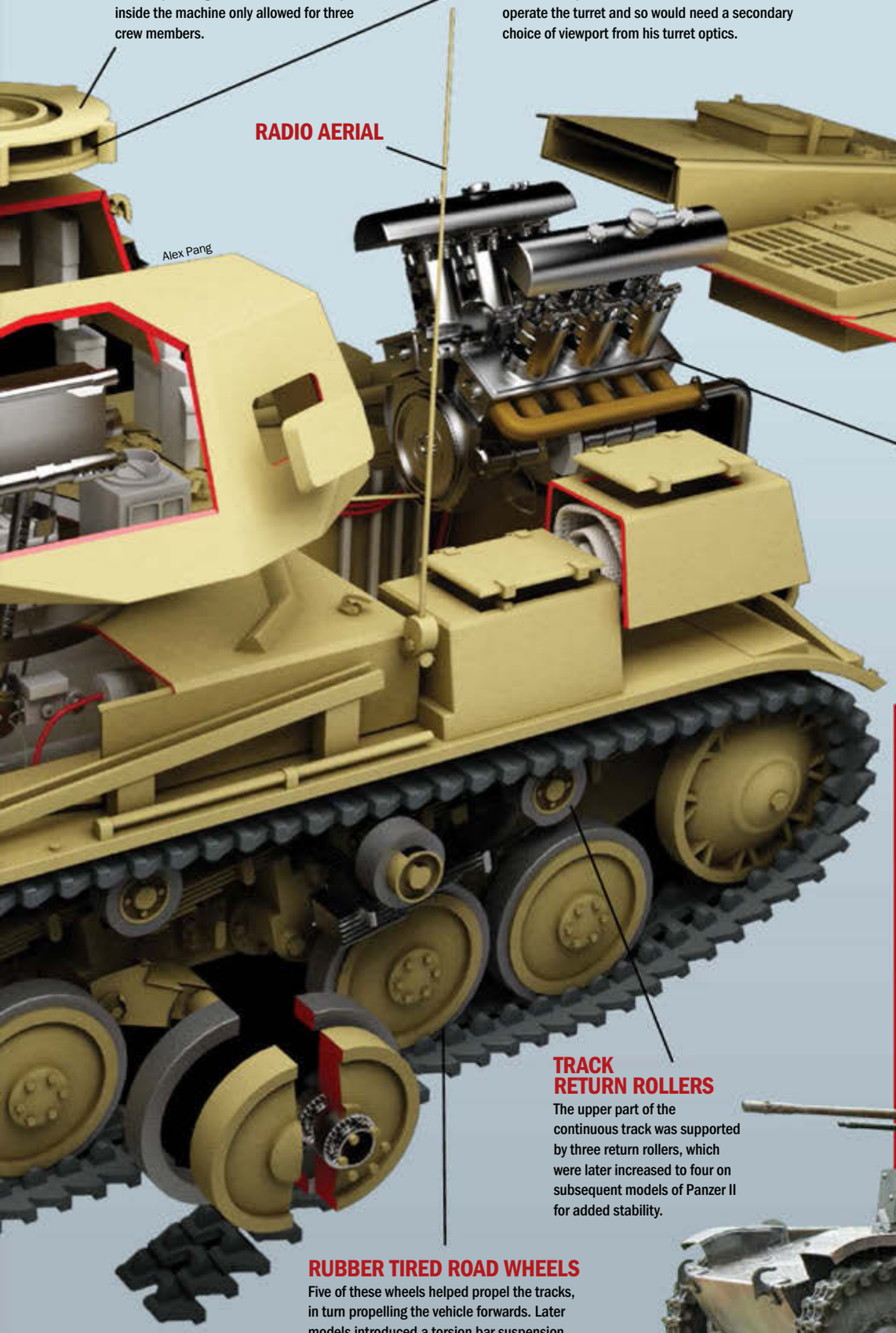
VISION PORTS

These were plentiful on the Panzer II, and absolutely essential in both offensive and defensive capacities. A Panzer II commander would operate the turret and so would need a secondary choice of viewport from his turret optics.

HOMOGENOUS STEEL ARMOUR

Early Panzer IIs came with only 14mm of armour on the front, sides and back. This was later increased to 30mm, and then to 35mm, but was still largely useless against anti-tank weaponry.

RADIO AERIAL



SIX-CYLINDER MAYBACH PETROL ENGINE

The Maybach HL 45 was a six-cylinder petrol engine that saw service in several German vehicles during the Second World War. It was designed to provide the Panzer II with speed without sacrificing mobility.

DESIGNED UNDER FALSE PRETENCE

With the end of the First World War came the Treaty of Versailles. Among many things limiting Germany were restrictions to her military rights, preventing her from producing armoured vehicles except for a few designated for security. To get around this, the German military ordered the Panzer II be produced under the designation Landwirtschaftlicher Schlepper 100, meaning that it was developed under the guise of being a farm tractor. This was common practice for Germany, and ensured that she wasn't in short supply of armour when war rolled around.

TRACK RETURN ROLLERS

The upper part of the continuous track was supported by three return rollers, which were later increased to four on subsequent models of Panzer II for added stability.

RUBBER TIRED ROAD WHEELS

Five of these wheels helped propel the tracks, in turn propelling the vehicle forwards. Later models introduced a torsion bar suspension system for the wheels, whereas early models favoured leaf-type springs.

ROLLS-ROYCE ARMOURED CAR

It may nowadays be an ultimate symbol of luxury, but from 1914 onward the Rolls-Royce found itself engaged on the frontline of the Great War

All manner of military vehicles were created in the haste to arm for World War I. The coming of the tank receives the most attention, but armoured cars also played a huge role in both the Great War and the various conflicts of the inter-war period. One of the most famous of these vehicles was the Mark I version of the Rolls-Royce Armoured Car. Based on the 1906 Silver Ghost, it was first developed in the UK in 1914 and was a military update of the civilian chassis. The once-luxury car was transformed into a military machine ready for battle.

Used sparingly for infantry support on the frontline, its armoured body and Vickers machine gun made it extremely effective for internal security, policing and quelling colonial uprisings. They were used in many theatres of the war as well as the 1916 Easter Rising and the 1922-23 Irish Civil War. Some even stayed in service until World War II, where they saw action against the Italians with the 11th (Prince Albert's Own) Hussars in Egypt. Armoured cars were not in the same league as tanks for firepower or brute strength but were useful for their manoeuvrability. Their distribution in great numbers allowed tanks to be more densely spread across the conflict and deployed only where they were most needed. The versatility and speed of the Mark I, which entered service in 1920, across various theatres and in various configurations, set the benchmark for future armoured cars.

The Irish purchased armoured cars in large quantities after the 1922-23 civil war

ROLLS-ROYCE ARMOURED CAR MARK I

MANUFACTURED: 1920
ORIGIN: UK
LENGTH: 5 METRES (16.4 FEET)
WEIGHT: 4.7 TONS
ENGINE: SIX CYLINDER
FUEL: PETROL
MAXIMUM SPEED: 97KM/H (60MPH)
CREW: 3-4
PRIMARY WEAPON: .303 WATER-COOLED VICKERS MACHINE GUN
SECONDARY WEAPONS: HOTCHKISS AIR-COOLED MACHINE GUN, CREW'S SIDEARMS

"ITS ARMOURED BODY AND VICKERS MACHINE GUN MADE IT EXTREMELY EFFECTIVE FOR INTERNAL SECURITY, POLICING AND QUELLING COLONIAL UPRISINGS"

This is the 1920 Pattern (E1949.329) version of the Rolls-Royce

The Vickers was used on a ball-mounting mechanism, which improved its aim and range of fire

VICKERS MACHINE GUN

The main armament of the Rolls-Royce Armoured Car was a .303 water-cooled Vickers machine gun. Operating from the self-turning turret above, the gunner could spray their target with bullets while being shielded from return fire. The Vickers was used extensively in all theatres of World War I and was an effective weapon against infantry. On the armoured car, it could suppress insurgents and uprisings with ease. As well as the Vickers, each member of the crew carried sidearms, and a Hotchkiss air-cooled machine gun was often stowed aboard for dismounted use.

The engine had some of the thickest armour plating on the whole vehicle as the car would be a sitting duck if it were disabled

"OPERATING FROM THE SELF-TURNING TURRET ABOVE, THE GUNNER COULD SPRAY THEIR TARGET WITH BULLETS WHILE BEING SHIELDED FROM FIRE"

A crank handle was used to start up the engine, which was not ideal for conflict situations

ROLLS-ROYCE ENGINE

The heavy armoured body of the Rolls-Royce peaked at 13mm thick in critical spots so a powerful engine was required to shift the bulk. A six-cylinder water-cooled engine ran with minimal vibration and noise, which helped enormously with the armoured car's reconnaissance capabilities. The Mark I may have weighed 4,689 kilograms (10,337 pounds) but the engine still gave the vehicle 80 horsepower (60 kilowatts), which allowed it to reach a top speed of 97km/h (60mph). The engine itself was covered in armour to protect it from gunfire.

Although the tyres were vulnerable to gunfire, there are few reports of them being punctured

WHEELS AND TYRES

The metallic rims of the car's four wheels allowed it to traverse boggy ground and dirt tracks as well as tarmac and paved roads. The wheels were not protected by armour and punctures from gunfire could be an issue with the Mark I, so two spare tyres on either side were provided. The rear wheels were twin disc while the front two were single disc. As time wore on and newer updates arrived, the wheels were made thicker to protect from puncture and improve the ride quality.

ARMOURED CARS THROUGH THE 20TH CENTURY

HOW THESE MACHINES DEVELOPED FROM THE ROLLS-ROYCE TEMPLATE

SCHWERER PANZERSPÄHWAGEN

A loophole in the Treaty of Versailles meant there was no limit on German armoured car production. The Wehrmacht generals used this to their advantage and soon produced a fleet of Schwerer Panzerspähwagen (heavy reconnaissance armoured cars). During the war, they were primarily used as scout vehicles and came in six and eight-wheel versions.

BA-64

Coming into service in 1942, more than 9,000 of these lightly armoured vehicles were produced by the USSR. Skipping across the battlefields, it was used to quickly and safely transport army officers. Its speed and mobility made it a useful asset on the Eastern Front against the armies of the Third Reich.

M1117 ARMORED SECURITY VEHICLE

Used frequently by the US Army from its inception in 1999, the M1117 is the modern update of the armoured car. Essentially a heavy-duty version of the popular Humvee, it has been used extensively in conflicts in the Middle East and was developed after the Battle of Mogadishu.

The rear side of the Rolls-Royce was an open tray and was very different to the pre-war civilian version

The driver saw the road ahead through a narrow opening that helped protect the occupants from gunfire and shrapnel

The riveted steel armour protected the engine and was continually reinforced and strengthened in later models of the armoured car

Extra support troops could hop on for a ride on the small bench on the back of the vehicle

REAR DECK

With only limited space for the crew of four inside the turret, the rear deck of the vehicle was utilised to carry extra loads. The crew's food and water was located here as well as other supplies and tools for maintenance in case of breakdown. Extra weapons and ammunition were also kept here for longer conflicts. The design made the Mark I look like a pickup truck and the Hotchkiss machine gun could be set up on the rear to fire from the back of the vehicle.

The car's side panels provided extra space to carry soldiers and supplies

"ARMOURED CARS WERE ALSO USED EXTENSIVELY IN LAWRENCE OF ARABIA'S OPERATIONS AGAINST THE TURKS"

World War II armoured cars removed the Vickers and instead used a Boys anti-tank rifle in an open turret

The front of the vehicle could be vulnerable due to the lack of armour on the tyres

ARMOURED CARS ACROSS THE EMPIRE

THE ROLLS-ROYCE WAS SENT OUT ACROSS THE WORLD TO ASSIST THE BRITISH WAR EFFORT

WORLD WAR I

At the start of the war, armoured cars were quickly snapped up by the RNAS (Royal Naval Air Service) for use in patrols in Dunkirk. They were also used extensively in Lawrence of Arabia's operations against the Turks. Two squadrons were even sent to Gallipoli, one of Britain's biggest failures of the war.

IRISH CIVIL WAR

After being used to help quash the 1916 Easter Rising, the Rolls-Royce was once again pressed into action across the Irish Sea in the 1922-23 civil war. Fighting on the side of the Irish Free State Government, they participated in street conflicts in Dublin, Cork and Waterford.

WORLD WAR II

Despite being relatively dated, there were still 76 Mark I 1924 Pattern vehicles in active service in 1941. An upgrade of the original model had also been commissioned and was called the Fordson. Equipped with a Boys anti-tank rifle, it policed the British-occupied Middle East.

THE TANK MUSEUM

Situated in the Bovington Army Camp in Dorset, The Tank Museum was opened in 1947. It contains more than 300 vehicles from 26 different countries, from the World War I Mark I tank to the currently serving Challenger 2. The Rolls-Royce Armoured Car was given to the museum in 1949 and is still in good working order. The Rolls-Royce opens the show at the museum's yearly Tankfest event, the world's best display of historic moving armour, held on the last weekend of June. Visit www.tankmuseum.org for the museum's opening hours and admission information.

Images: Bovington Tank Museum

A7V TANK

One of the earliest tanks to be produced, the A7V was supposed to deliver German soldiers a mobile fortress to break through Allied lines, but wasn't a great success…

Designed specifically to counter the emergence of British tanks on the Western Front during World War I, the A7V was a medium-armoured tank designed by the German General War Department in 1916. The vehicle resembled a mobile pillbox or APC (armoured personnel carrier) and delivered a steel-plated body with the capacity to hold 18 soldiers, a 57-millimetre (2.2-inch) cannon and six to eight 7.9-millimetre (0.3-inch) machine guns (for a full hardware breakdown see 'Anatomy of an A7V' diagram). Its role, as hinted at by its German classification – Sturmpanzer-Kraftwagen translates roughly as 'assault armoured motor vehicle' – was to assault and break through fortified Allied lines, as armies became increasingly entrenched.

The first preproduction A7V was delivered in September 1917 and was closely followed by the first production model in October of the same year. Despite this, the first deployment of the A7V had to wait until March 1918, where five of the total 20 made were deployed north of the St Quentin Canal in northern France. Unfortunately, this is where the first design flaws of the vehicle were initially encountered. Three of the five tanks broke down during operation due to mechanical faults.

Despite these issues, the A7V fleet was then deployed en masse, with 18 vehicles partaking in the Second Battle of Villers-Bretonneux in April 1918. Although reports from Allied soldiers at the time state that the A7V's armour made direct attack from their handheld weapons impossible, the A7V's modest armour was easily breached by the Allied Mark IV's six-pounder cannons. Further, due to the low clearance and crude design of the A7V's suspension and tracks, many got stuck on difficult off-road terrain and two even toppled over into holes. In addition, after a swift counterattack by Allied forces, three of the stranded A7Vs were captured.

As such, even though 100 A7Vs had originally been ordered, their limited impact led to the programme to be scrapped before the end of the war, with many of the remaining vehicles dismantled as early as October 1918. Today, no original A7V has survived, with the majority scrapped. However, a replica based on original designs was built between 1987 and 1990 and can now be viewed at the Panzermuseum in Munster, Germany.

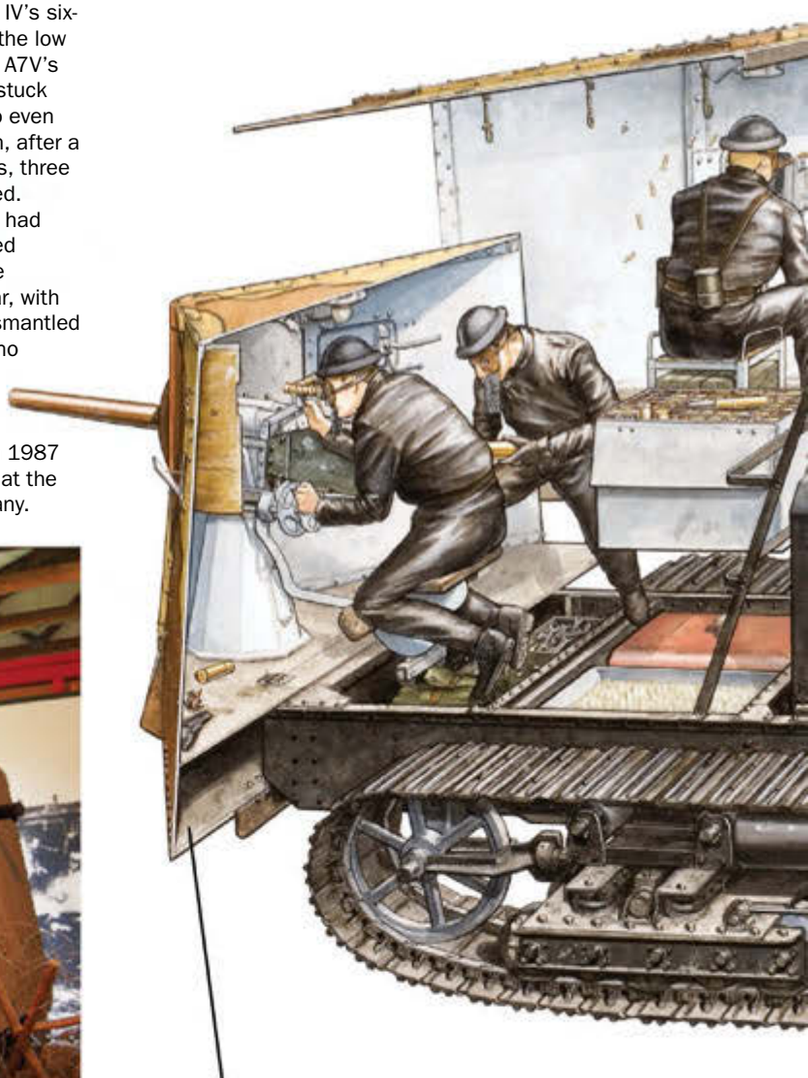
A replica of an A7V based on original schematics is viewable today at the Panzermuseum in Munster, Germany

ANATOMY OF AN A7V

WE BREAK DOWN THIS WORLD WAR I TANK TO SEE HOW IT WAS BUILT AND HOW IT OPERATED

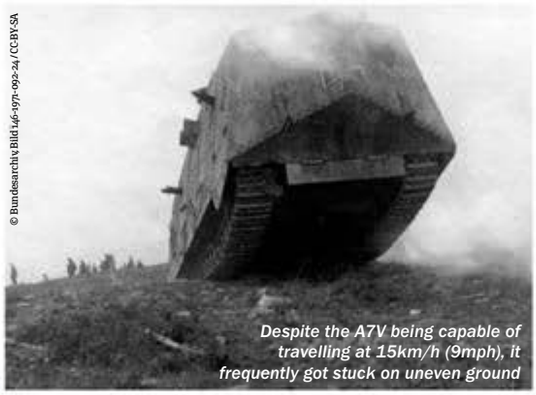
ARMOUR

Despite having 20mm (1.2in) steel plate at the sides, 30mm (0.8in) at the front and 10mm (0.4in) on the roof, the A7V was easily penetrated by cannon fire. This was because the steel was not hardened armour plate. As such, it could only stop small arms fire.



ARMAMENT

The main weapon of the A7V was a 57mm (2.2in) Maxim-Nordenfelt cannon, which was equipped to all male variants. The secondary armament was a series of six to eight 7.9mm (0.3in) MG08 machine guns. The tank could carry 180 shells for the cannon.



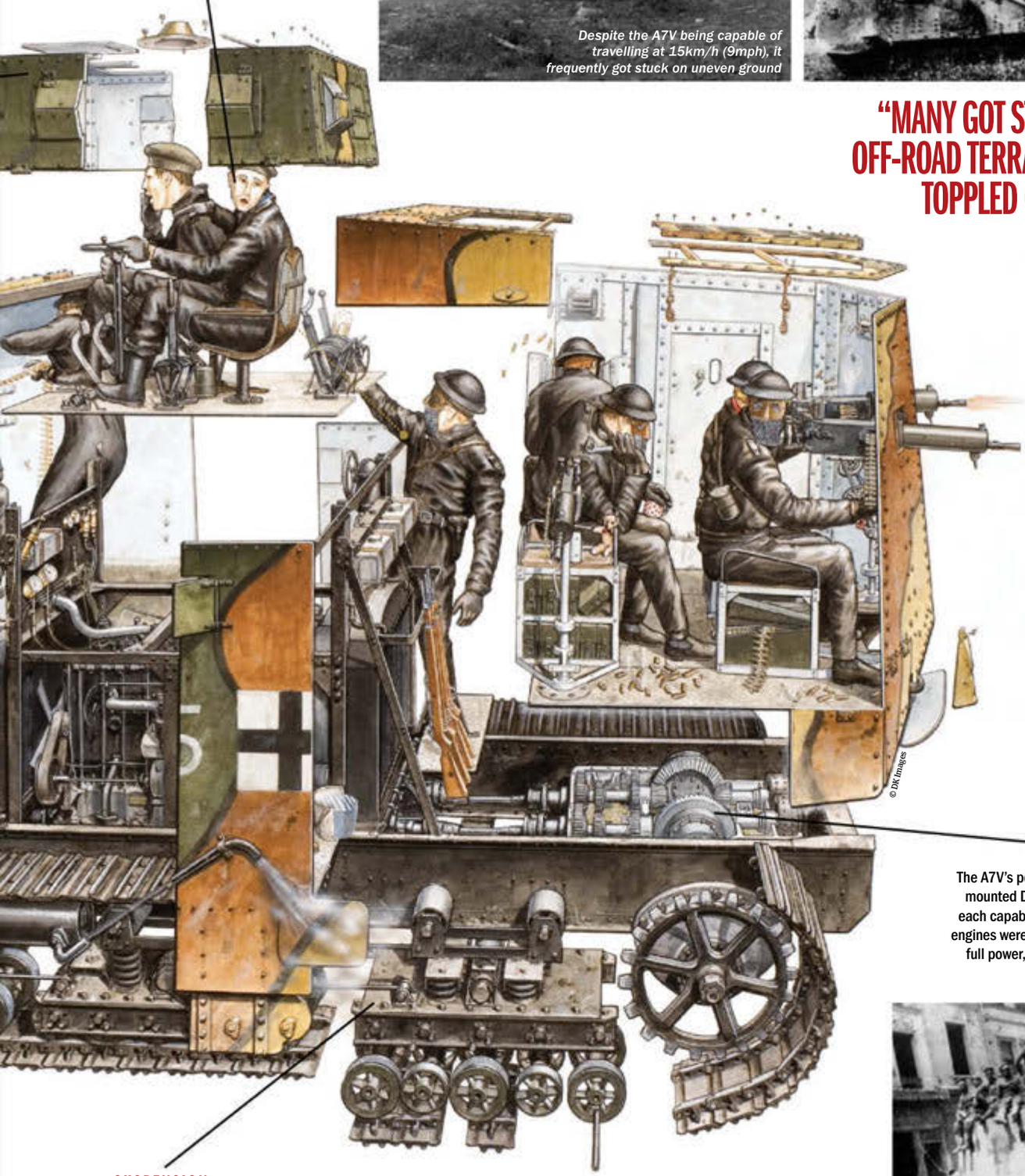
Despite the A7V being capable of travelling at 15km/h (9mph), it frequently got stuck on uneven ground

A shot of an A7V and its crew from July 1918

CREW

An A7V's crew consisted of 17 soldiers and one officer. These were needed for the following roles: commander, driver, mechanic, two artillery men (gunner and loader) and 12 infantry men (six gunners and six loaders).

"MANY GOT STUCK ON DIFFICULT OFF-ROAD TERRAIN AND TWO EVEN TOPPLED OVER INTO HOLES"



A7V

CREW 18
HEIGHT 3.3M (11FT)
WIDTH 3.1M (10FT)
LENGTH 7.3M (24FT)
WEIGHT 30 TONS
ENGINE 2 X DAIMLER FOUR-CYLINDER PETROL (149KW/200HP TOTAL)
SUSPENSION HOLT TRACK, VERTICAL SPRINGS
MAX SPEED 15KM/H (9MPH)
MAX RANGE 80KM (50MI)
ARMOUR SIDES: 20MM (0.8IN); FRONT: 30MM (1.2IN); ROOF: 10MM (0.4IN)
MAIN ARMAMENT 57MM (2.2IN) MAXIM-NORDENFELT CANNON
SECONDARY ARMAMENT 6 X 7.9MM (0.3IN) MG08 GUNS

ENGINE

The A7V's power came courtesy of two centrally mounted Daimler four-cylinder petrol engines, each capable of generating 75kW (100hp). The engines were fed by a 500l (132ga) fuel tank. At full power, the A7V could travel at a maximum speed of 15km/h (9mph).

An A7V on the Western Front in March 1918

SUSPENSION

The A7V was equipped with helical springs, rear-drive sprockets, front-mounted idlers and 24 roller wheels in bogies. The lack of shock absorbers made the ride incredibly bumpy and the low clearance (ie 190-400mm/7.5-15.7in) led to poor off-road capabilities.

TIGER I

One of the most advanced Axis panzers of the Second World War, the Tiger I struck fear into the hearts of Allied tank divisions

Between August 1942 and the fall of the Third Reich, approximately 1,500 Panzerkampfwagen VI Tiger Ausf.E were manufactured by the Nazi war machine.

Renowned for its accuracy and strong armour, this heavy tank was a formidable foe to the Allied forces. It outclassed many of the Sherman tank models in several departments and tales told from the war have described 75mm rounds bouncing straight off the Tiger's solid armour.

The tank saw its first action in September 1942 as the Third Reich advanced eastwards under Operation Barbarossa. In an engagement near Leningrad, four Tigers managed to dispatch 24 Soviet T-34 tanks. In fact, the Tiger only floundered when it ended up becoming stuck in the harsh conditions the

PANZERKAMPFWAGEN VI TIGER AUSF.E

COMMISSIONED: AUGUST 1942
ORIGIN: KASSEL, GERMANY
LENGTH: 8.45M (27.7FT)
RANGE: 5,000M (16,404FT)
ARMOUR: ELECTRO-WELDED INTERLOCKING NICKEL-STEEL PLATES
ENGINE: MAYBACH HL 210 P45
PRIMARY WEAPON: 88MM CANNON
SECONDARY WEAPONS: 7.92MM MG-34 MACHINE GUNS
CREW: 5

Russian winter, where its caterpillar tracks would be repeatedly trapped in the dense, frozen mud of Eastern Europe. This meant the nimble T-34 could now outmanoeuvre the Tiger and strike where the armour was weakest. The Allies had no answer to the sheer power of Panzerkampfwagen VIs until the development of the Sherman Firefly in 1943, which finally matched Tigers pound for pound. Before this, only wave after wave of Shermans and T-34s could bring about the downfall of a Tiger.

By 1944, German factories had hurried the Tiger II into production and the numbers of the Tiger I dwindled. Contemporary reports suggest that the Tiger I was over-engineered and, towards the latter stages of its lifespan, rushed off the production line as the Nazis desperately tried to save the war.

A Tiger I tank rolling across the battlefields of Europe was a frightening sight for any Allied soldier

Bundesarchiv, Bild 101I-299-1805-16 / Scheck / CC-BY-SA

"THE ALLIES HAD NO ANSWER TO THE SHEER POWER OF PANZERKAMPFWAGEN VIs UNTIL THE DEVELOPMENT OF THE SHERMAN FIREFLY"

Above *The tank has insignia showing its battalion and allegiance to the German Wehrmacht. This particular model was found abandoned in the North African desert*

Bundesarchiv, Bild 101I-022-2936-27 / Altvater / CC-BY-SA

88MM GUN

The main weapon of the Tiger could shatter the defences of Allied tanks and fortifications. The 88mm gun could penetrate 100mm of armour from up to 1,000 metres (3,280 feet) away. On the battlefield, the Tiger would be strategically placed on hilltops to make use of its cannon's long range while being protected from enemy fire by its thick armour.

Above: *The panzer's ammunition varied from armour-piercing shots to high explosive and incendiary rounds*

Bundesarchiv, Bild 183-J14931 / Rottensteiner / CC-BY-SA.jpg

The huge 88mm Panzergranate 39 gun dwarfed the allied M4 Sherman cannon and was originally an anti-aircraft gun

CATERPILLAR TRACKS

The tracks fitted on a Tiger were extremely wide. This helped the bulky 57-ton tank traverse over boggy ground as well as spreading the weight more thinly to cross bridges. Despite this, the Tiger was the victim of adverse weather conditions on the Eastern Front as frozen mud wedged itself within the tracks. The lightweight soviet T-34s didn't experience this problem as frequently and were able to outflank the Nazi tanks – particularly at the 1943 Battle of Kursk, which was the biggest tank battle of all time.

SECONDARY WEAPONS AND AMMUNITION (TWO 7.92 MG-34 MACHINE GUNS)

As well as its main cannon, the Tiger was fitted with MG-34 or MG-42 machine guns. A Tiger tank would have one next to the driver at the front of the tank and on some models an MG would be attached to the top of the vehicle. These machine guns could reach distances of up to 400m (1,312ft) and 5,850 rounds would be kept aboard to cut down swathes of infantry and light vehicles.

THE TIGER II

THE TIGER WASN'T THE MOST FEARSOME OF THE NAZI PANZERS. THE TIGER II WAS BIGGER, STRONGER AND BETTER PROTECTED

MAIN GUN

The Tiger II's main gun packed a marginally more powerful punch than the Tiger I as it could penetrate 182mm (seven inches) of armour at double the distance. This was also further than Allied tanks of the period. Known informally as the Königstiger, only 492 of these mighty machines were made.

ARMOUR

The armour was nearly 200mm thick on the Tiger II, and significantly more than its predecessor. The Allies tried to create equivalents but tanks such as the American T29 were not ready for World War Two. The Tiger IIs were rushed into production and were often hampered by ill-suited engines.

KING-SIZE

The Tiger II was a heavy tank and its bulk was even larger than the Tiger I. The original Tiger already had issues with its engine so the larger size of the Tiger II emphasised these problems even more. Only in use at the tail end of the war, we will never know how it could have contributed to the earlier stages of the war.

Images: Bundesarchiv, Hamann / Wagner

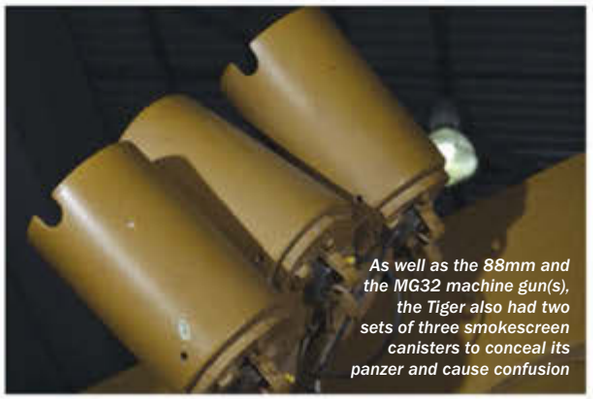
INTERIOR

The Tiger's small enclosed interior contained a crew of five: a gunner, loader, driver, commander and a radio operator. Although small, the Tigers were over-engineered by their manufacturers, so the interior was packed with modern sighting equipment, weapons caches and tools. The drivetrain was aided by hydraulic-power-assisted steering and the entire mechanism was powered by four batteries. The whole tank was so advanced that when it was captured by the British, it was inspected by Winston Churchill and George VI and then taken back to Britain for extensive testing.

Despite its large exterior, the inside of a Tiger was a cramped place where fires were a frequent problem

Below: *The Germans insisted on using a 641bhp (478kW) 21 litre petrol Maybach HL210 engine in their Tiger I tank*

Below: *The panzer contained an escape hatch if the main lids were under fire or had been blown off*



As well as the 88mm and the MG32 machine gun(s), the Tiger also had two sets of three smokescreen canisters to conceal its panzer and cause confusion

THE TIGER 131

This Tiger model was part of the 504 Schwere Panzer Battalion in North Africa and was one of the very few not to have been destroyed by its own crew. Forensics and analysis have shown that the Tiger was hit several times by British Churchill tanks but none disabled the tank. The main damage was dealt just underneath the barrel and wedged the turret to the hull. This stopped it from working, but could easily have been repaired by the crew. This makes it even stranger that the crew abandoned it and didn't destroy it as they were instructed to. It's the only working Tiger currently in existence and was featured in the 2014 film *Fury*.

The Tiger had a complex exhaust system on its rear to increase power

Below: *The well-engineered Tiger was a box of tricks and had cables and even a spade to help retrieve it from sticky situations*

THE TANK MUSEUM

Situated in the Bovington Army Camp in Dorset, The Tank Museum was opened in 1947. It contains over 300 vehicles from 26 different countries, from the First World War Mark I tank to the currently serving Challenger 2. Tiger 131 was given to the museum in 1951 and is one of the most popular tanks in the entire museum. There is now a 'Tiger Day' every spring, which explores the history of the tank, as well as its many contemporaries from the Second World War. **Visit www.tankmuseum.org for opening hours, admission information and more!**

The massive 88mm gun could take out almost everything on the Second World War battlefield

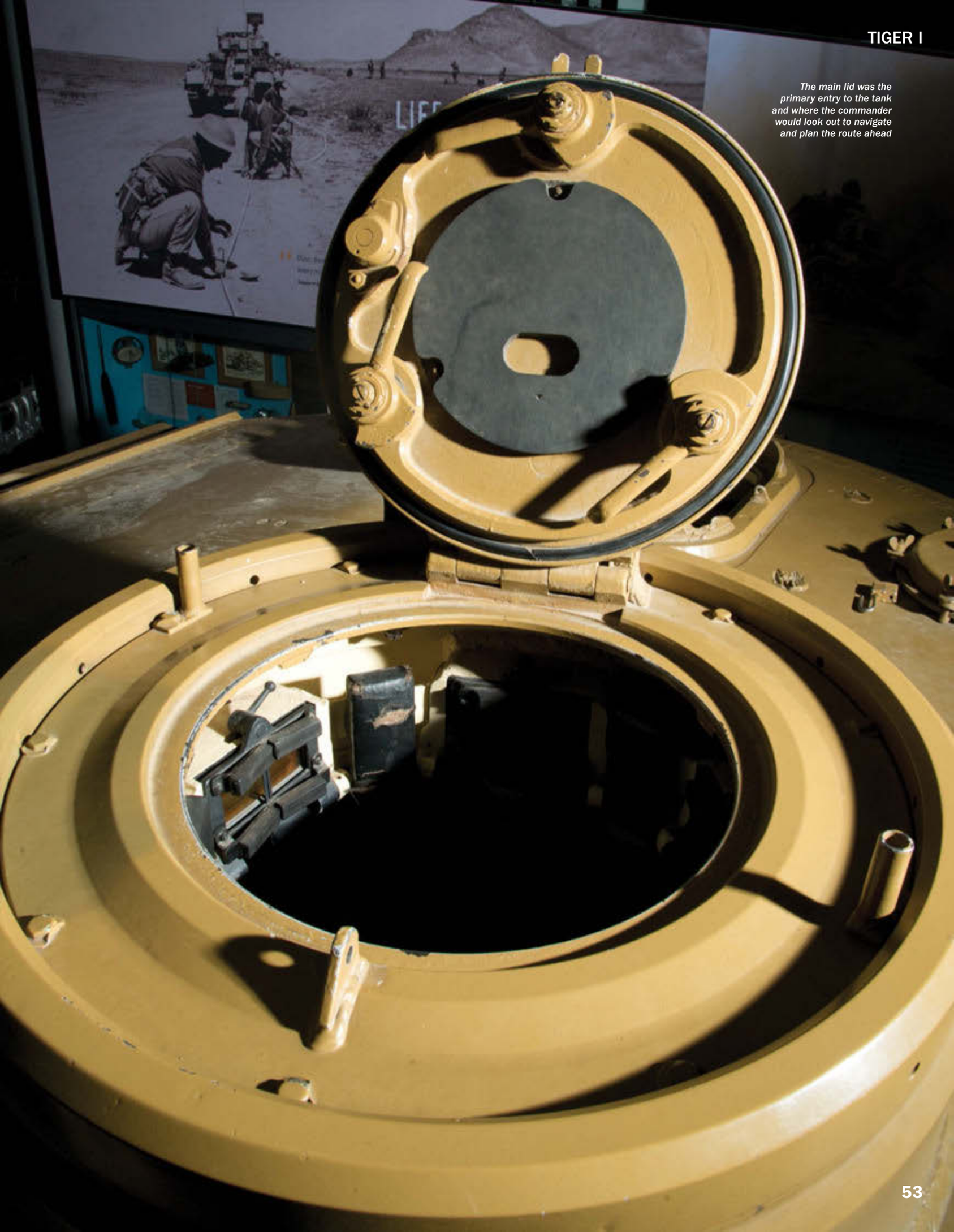
TIGERS? WHAT ABOUT PANTHERS!

Just below the heavy Tiger tank in the power stakes was the medium Panzer V or Panther tank. An excellent all-rounder, it had top of the range capabilities in everything from speed, to firepower and manoeuvrability. The idea for the Panther came after the previous model of Panzer IV tanks were being outclassed on the Eastern Front by the Soviet T-34. The Wehrmacht captured the Red Army's prize tank and got to work creating a better alternative. The Panther was born as a result. One of the Panther's first conflicts was at Kursk. Plagued by mechanical issues, it did not perform well in its first acid test as the Wehrmacht lost out to the Red Army in what was the largest tank battle of all time. After this initial setback however, the Panzer V went from strength to strength and accounted for almost half of the German tanks on both the Western and Eastern fronts. Like the Tiger, it consistently outclassed both the M4 Sherman and the original T-34 but ultimately fell foul of the overwhelmingly superior Allied numbers, as well as the development of large guns to help effectively combat them.

Above: *According to many historians, the Panther was the best tank of the entire Second World War*

THE THIRD REICH PRODUCTION LINE

The technology inside German tanks during the Second World War was second to none. However when the USA entered the war and the Soviet production line thudded into gear, the Third Reich simply could not cope. When Albert Speer became Minister of Armaments and War Production in 1942, the amount of panzers leaving the factories did increase but it was simply not enough. The issue was in the German tendency to over engineer their tanks. Despite boasting far better attributes than their rivals in almost every department, there simply weren't enough German tanks to hold the line on the battlefield. When the time of the Tiger I came about, it was already too late so they were mostly used, albeit very effectively, in a defensive capacity. On the Western Front in particular, the Tiger dominated the US M4 Sherman but as the Allied numbers poured through Europe and outflanked the Axis in Operation Overlord, even the powerful Tiger couldn't hold its ground. In the final year of the war, the German tanks were rushed through production so they could try and stem the flow of Allied troops. However this still posed problems as the engineering worsened and the German panzers, especially the Tiger II, suffered and with failing Armoured Divisions, the war was as good as lost.



The main lid was the primary entry to the tank and where the commander would look out to navigate and plan the route ahead

© Hohum

The Churchill Mark IV weighed an incredible 38.5 tons

The Churchill tank typically operated with a five-man crew

CHURCHILL TANK

The most successful British tank series during World War II, the Churchill was a defensive powerhouse and a versatile weapons platform

Designed in the aftermath of the evacuation of Dunkirk by the British Expeditionary Force, the Churchill tank was Britain's attempt to readdress the technology gap between their ageing Matilda II battalion and the German Panzer tanks that had them out-gunned. The result was the Mark I, a heavily armoured battle tank equipped with a two-pounder main gun, three-inch howitzer in the rear and the most advanced and robust suspension system yet conceived. It was a defensive juggernaut, designed with one goal: to dominate the European theatre of war.

From its introduction in June 1941, the tank proved a reliable and versatile weapon platform capable of engaging targets quickly and efficiently. Key to this was its high speed of 26km/h (16mph) and excellent turning ability, characteristics made possible by its multiple-bogie suspension system. The suspension was fitted to the hull under two large pannier enclosures on either side, with the tracks running over the top.

The tracks moved over a series of ten-inch wheels, which themselves were fitted to 11 bogies (a wheeled framework) on either side of the vehicle. The suspension took the main weight of the Churchill tank on nine of its 11 bogie pairs, with the front set used when nosing into the ground on steep terrain and the rear set used as a track tensioner. Due to the sheer number of wheels and wrap-round-pannier tracks, this allowed the Churchill tank to operate even when parts of the system were damaged in combat, keeping the tank moving and operational.

Due to the weight of the Churchill's armour plating, a massive powerplant was necessary to keep it moving at speed. This power came courtesy of a Bedford Vehicles horizontally opposed twin-six petrol engine, which could produce 350bhp at 2,200rpm and delivered 960 pounds of torque. The engine was controlled through a Merritt-Brown gearbox with an in-built regenerative breaking system. This allowed the tank to be steered by changing the relative speeds of the two tracks and, when put in its lowest gear, perform a neutral turn on the spot. This ability to turn so rapidly earned the Churchill much praise and made engaging moving targets considerably easier than in previous models.

Initially, the Churchill was fitted with a two-pounder main gun and three-inch howitzer (artillery piece); however, the former was soon upgraded to a six-pounder cannon and the latter replaced with a high-calibre machine gun. These cannons gave the Churchill decent stopping power against medium armour, yet still left them short in firepower compared with their German counterparts. The Churchill's main cannon continued to be improved, with 75mm guns fitted to Mk IIIs.

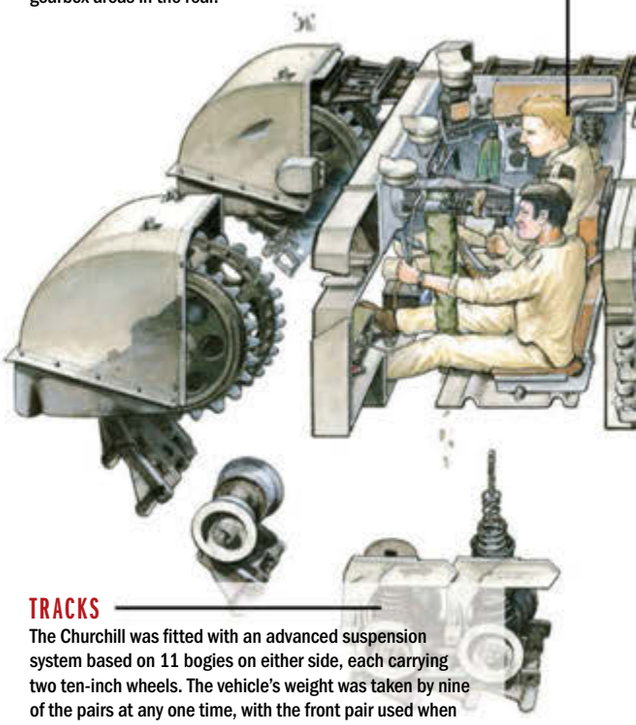
Despite its average firepower, however, the Churchill's high manoeuvrability and excellent armour made it one of the foremost tanks of WWII, being extensively deployed in Europe and North Africa.

ARMAMENT

The Mk VII was armed with a 75mm cannon, which was housed in a composite turret. The gun allowed the tank to engage German armoured vehicles and buildings, but lacked the penetration against heavily armoured targets. Machine guns and even flamethrowers were attached to other models.

CREW

The Churchill was operated by five crew, consisting of a commander, gunner, radio operator, driver and co-driver. These inhabited four separate compartments within the hull, with the driving position located at the front, fighting compartment in centre and engine and gearbox areas in the rear.



TRACKS

The Churchill was fitted with an advanced suspension system based on 11 bogies on either side, each carrying two ten-inch wheels. The vehicle's weight was taken by nine of the pairs at any one time, with the front pair used when nosing into the ground and the rear pair as a track tensioner.


© TankMuseum, Bovington

BLOWING THE LID OFF THE CHURCHILL MK VII

WE BREACH ONE OF THE MOST SUCCESSFUL CHURCHILL VARIANTS TO DISCOVER WHAT MADE IT SO RUTHLESS, RELIABLE AND ICONIC


A Churchill Crocodile (converted Mk VII) featured a high-powered flamethrower capable of firing bursts over 137m (150 yards)

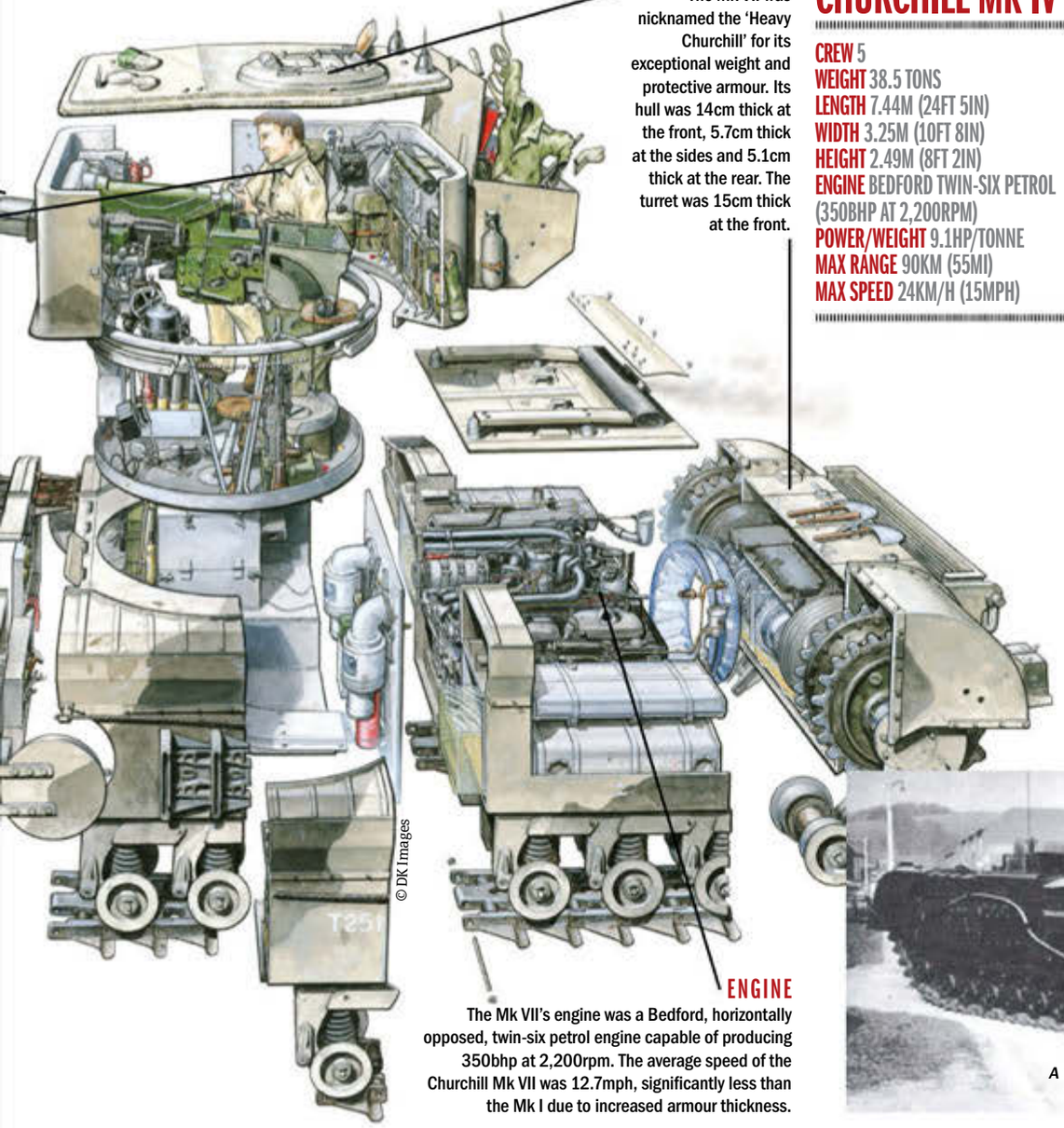

A surviving Churchill mounted on top of a Churchill Bridgelayer's disconnected bridge
© Elliot Simpson-geograph.org.uk

CHURCHILL MK IV

CREW 5
WEIGHT 38.5 TONS
LENGTH 7.44M (24FT 5IN)
WIDTH 3.25M (10FT 8IN)
HEIGHT 2.49M (8FT 2IN)
ENGINE BEDFORD TWIN-SIX PETROL (350BHP AT 2,200RPM)
POWER/WEIGHT 9.1HP/TONNE
MAX RANGE 90KM (55MI)
MAX SPEED 24KM/H (15MPH)

ARMOUR

The Mk VII was nicknamed the 'Heavy Churchill' for its exceptional weight and protective armour. Its hull was 14cm thick at the front, 5.7cm thick at the sides and 5.1cm thick at the rear. The turret was 15cm thick at the front.


© DK Images

ENGINE

The Mk VII's engine was a Bedford, horizontally opposed, twin-six petrol engine capable of producing 350bhp at 2,200rpm. The average speed of the Churchill Mk VII was 12.7mph, significantly less than the Mk I due to increased armour thickness.

MAXIMUM VERSATILITY

FROM BRIDGE LAYER TO MINE CLEARER, THE CHURCHILL TANK WAS THE IDEAL BASE FOR A HOST OF SPECIALIST VEHICLES

Due to the Churchill's high manoeuvrability and advanced suspension system, it made a natural base for a number of specialist vehicles. Some highlights include the Churchill Crocodile, a variant of the tank that was fitted with a flamethrower for anti-infantry operations; the Churchill ARK, an armoured ramp carrier that could make mobile bridges to cross water hazards and difficult terrain; and the Churchill AVRE, a multi-use vehicle equipped with mine flails, Fascine rollers, explosive placers and a 290mm Spigot mortar for levelling buildings. In fact, the Churchill proved so versatile that late on in the war it was even converted into an Armoured Personnel Carrier (APC), with engineers removing its turret completely. This variant was called the Churchill Kangaroo, (see photo below).


A Churchill Kangaroo, the variant of the tank converted to be an Armoured Personnel Carrier

SHERMAN TANK

How this famous tank led the Allied war machines in WWII

The first use of the tank as a military weapon was in the First World War at the Battle of the Somme. Armoured vehicles would become a big part of warfare but it wasn't until the Second World War that they became essential. The most essential of all the Allied tanks was the Sherman.

Titled the M4 Medium Tank, it was named after William Tecumseh Sherman, who was a Union general in the American Civil War. It replaced the M3 armoured vehicle and was provided as part of the American Lend-Lease policy to its allies. It was first used in 1942 by the British, to tussle with the German Panzer IIIs and IVs for battlefield supremacy.

The Sherman was based on speed and manoeuvrability. It had weaker armour and less equipment than its German counterparts and with the introduction of the Axis' Tiger and Panther models, it became inferior on the battlefield. This was soon remedied with the introduction of the Firefly, Jumbo and Easy Eight variants. The tank's main tactic was to fire an armour-piercing round and then incinerate the unarmoured and exposed enemy tank. Shermans were always fielded in great numbers and worked well in partnership with M10 Tank Destroyers. The Sherman was used extensively in the African, French and Italian campaigns until the end of the war. Some models could attach a flamethrower, rocket launcher or bulldozer blade, as well as amphibious versions, which were used in the D-Day landings.

Even after the war had ended, the Sherman was still used frequently. Its reliability and low running cost allowed it to be deployed in the Korean War, as well as by other nations, with Australia, Brazil, Egypt and many more having their own specific variations of the successful Sherman model.

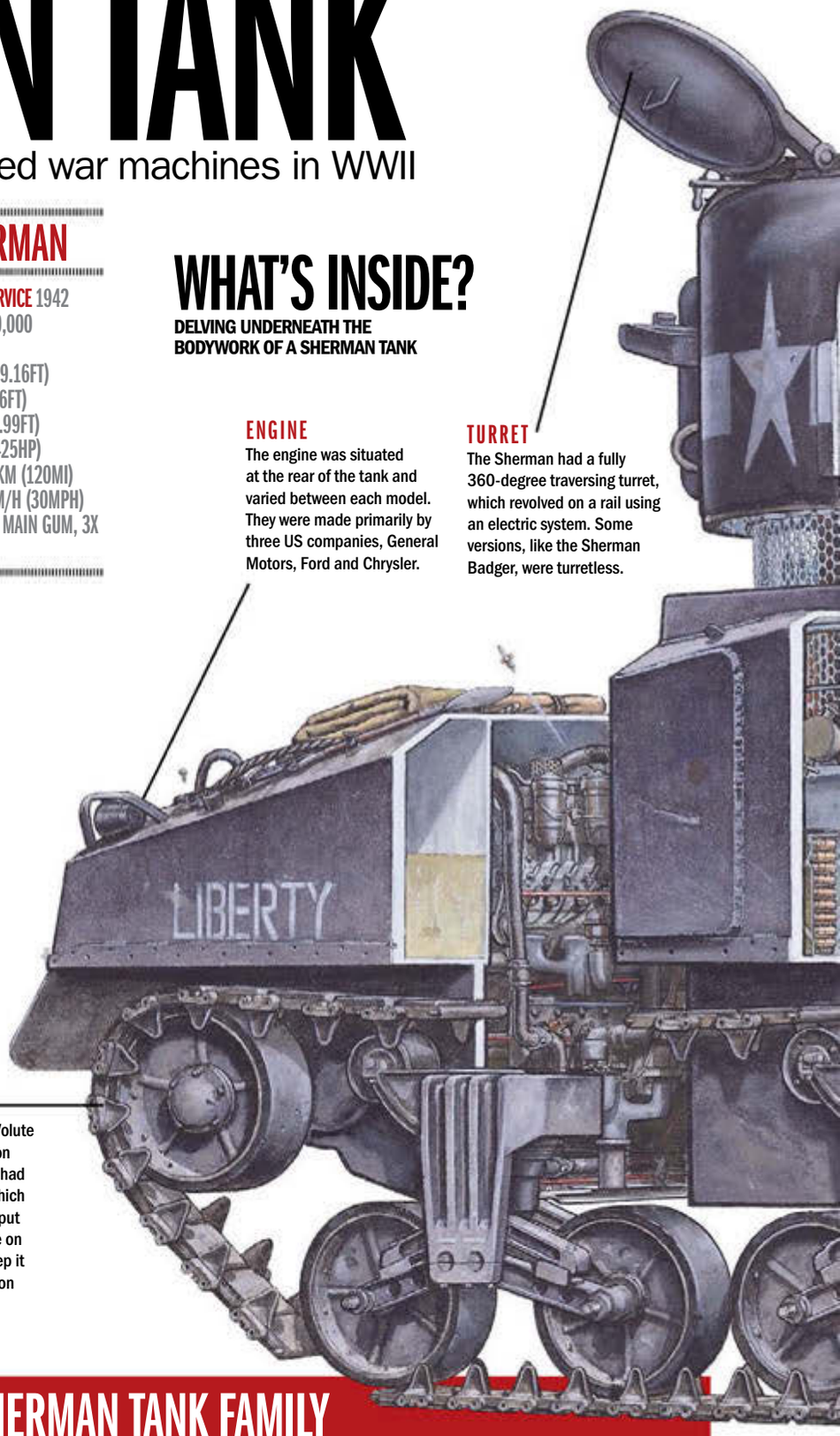
"IT WAS NAMED AFTER WILLIAM TECUMSEH SHERMAN, WHO WAS A UNION GENERAL IN THE AMERICAL CIVIL WAR"

M4 SHERMAN

FIRST YEAR OF SERVICE 1942
AMOUNT MADE 50,000
CREW 5
LENGTH 5.84M (19.16FT)
WIDTH 2.62M (8.6FT)
HEIGHT 2.74M (8.99FT)
ENGINE 317KW (425HP)
MAX RANGE 193KM (120MI)
MAX SPEED 48KM/H (30MPH)
WEAPONS 75MM MAIN GUM, 3X MACHINE GUNS

WHAT'S INSIDE?

DELVING UNDERNEATH THE BODYWORK OF A SHERMAN TANK



ENGINE
The engine was situated at the rear of the tank and varied between each model. They were made primarily by three US companies, General Motors, Ford and Chrysler.

TURRET
The Sherman had a fully 360-degree traversing turret, which revolved on a rail using an electric system. Some versions, like the Sherman Badger, were turretless.

TRACKS
Using a Vertical Volute Spring Suspension (VVSS), the tank had 78-link tracks, which was designed to put minimal pressure on the ground to keep it light and nimble on all terrain.

THE VARIOUS MEMBERS OF THE SHERMAN TANK FAMILY

1 M4A3E2 JUMBO
Designed for the liberation of Europe, the Jumbo weighed 38 tons, it was very well protected, resisting all German anti-tank guns.

2 M4A3E8 EASY EIGHT
Smaller and more mobile yet with the same armour as the Jumbo, this variant saw frequent postwar service, including in Vietnam.

3 M4A3R3 ZIPPO
Known as a 'flamethrower tank', designed to flush out pillboxes and bunkers. It was mainly used in the Far East theatre of war.

4 T34 CALLIOPE
Carrying a rocket launcher, this tank variation only came into use at the tail end of WWII but was highly effective against fortified defences.

TOP GUN
The main Browning M2HB 12.7mm .50-calibre machine gun was located on the turret and was a rapid-fire anti-infantry alternative to the main Howitzer shells.

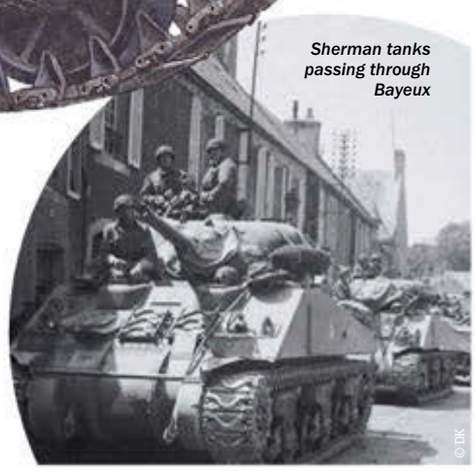
MAIN GUN
Most Sherman tanks utilised a 75mm main gun, which fired explosive shells. Later in the war, 76mm and 105mm versions were introduced for extra firepower.

DRIVING AND STEERING
The tank included five forward gears and two steering levers and the driver's vision was protected by metal hoods and bulletproof glass.

SIGHTS
Originally a periscopic sight, these had been changed by the African campaigns to high-power telescopic sights – an idea taken from the Germans – enabling far superior sight.

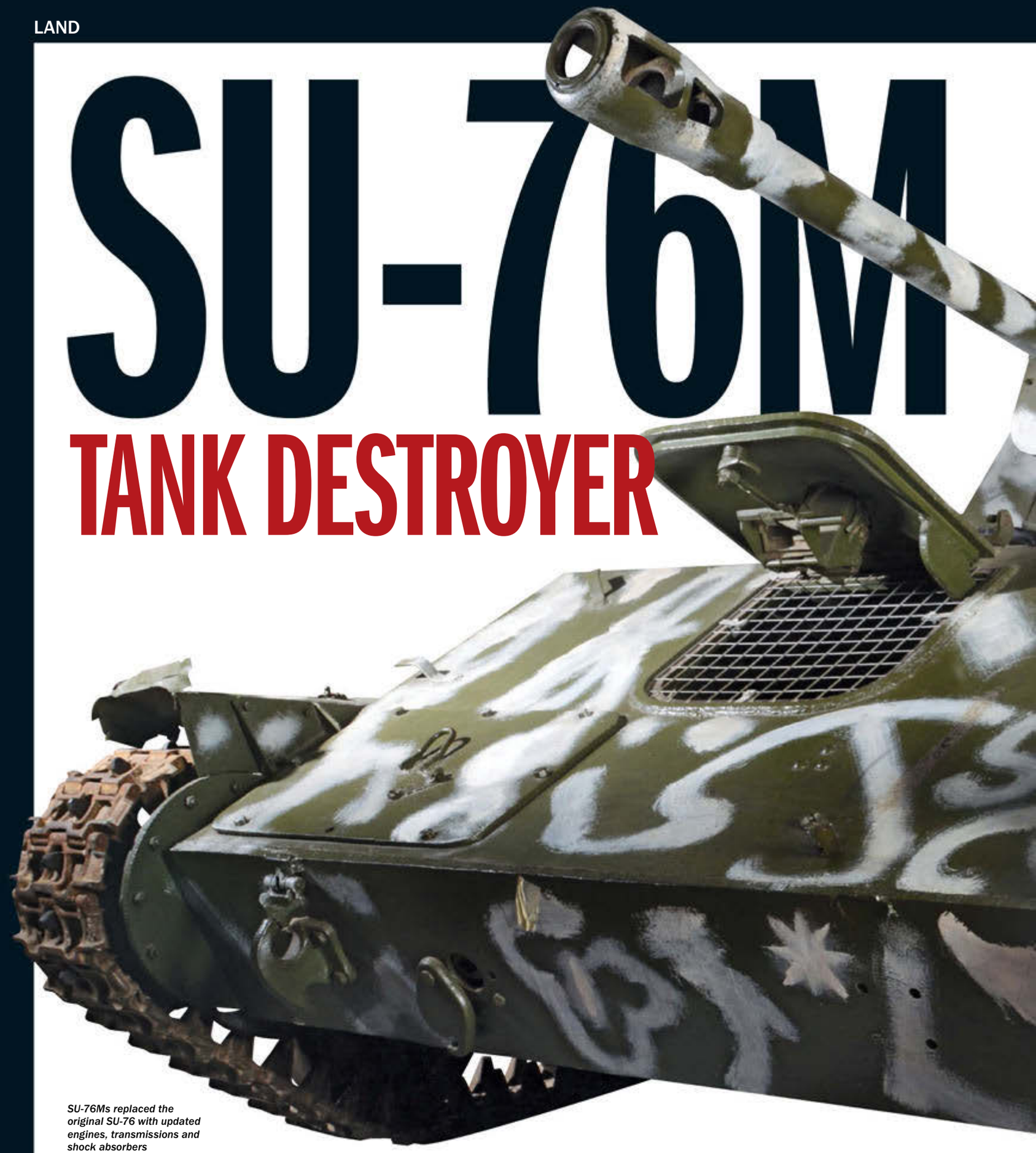
ESCAPE HATCH
To allow for quick escapes after sustaining damage, later models included an emergency hatch on the floor below the bow gunner.

MACHINE GUN
The bow gunner had a 7.62mm .30-calibre machine gun to strike closer and faster infantry. It was protected by a reinforced sloped front hull.



Sherman tanks passing through Bayeux

SU-76M
TANK DESTROYER



SU-76Ms replaced the original SU-76 with updated engines, transmissions and shock absorbers

Meet the tank killer that helped halt the German advance into Soviet lands and turn the tide of Russia's Great Patriotic War

If the First World War was the birth of tanks, the Second World War was the birth of tank killers. Used in high numbers by the Wehrmacht and Red Army (but not so much by the Allied powers). A field gun attached to a tank chassis would create a mobile heavy gun and an infantry support weapon in the field of battle. The SU-76M was the successor to the original SU-76 and was mass-produced by the USSR in an attempt to defeat the Panzers that were advancing ever eastwards. Production began in December 1942 and they became a triumph of Soviet handiwork. Hastily produced, they paled in comparison with their German equivalents but their sheer numbers (over 12,500 were built) meant they could easily outflank any German advance. This was a factor in the reverse in fortunes of the Germans on the Eastern Front at the Battle of Kursk.

After the end of the war, the SU-76M model was used in the Korean War on the side of the Communist forces of North Korea until it was phased out by more-modern vehicles and methods of warfare. Even when they were replaced, many were stripped of their guns and remodelled into ammunition carriers and battlefield recovery vehicles. There were many different SU-76s in the Red Army. The SU-7B had a closed crew compartment while the SU-76P and SU-76I were based on the Soviet T-26 and German Panzer III. The design also set out the template for the ZSU-37, which became the Soviet self-propelled AA gun of choice.

"THE SU-76M WAS MASS-PRODUCED BY THE USSR IN AN ATTEMPT TO DEFEAT THE FORMIDABLE RANKS OF PANZERS THAT WERE ADVANCING EVER EASTWARDS"

SU-76Ms used their camouflage and the terrain to stealthily advance upon unwitting enemy tank divisions

Soviet soldiers hitch a ride on an SU-76M as they liberate a German town

SU-76M

COMMISSIONED: DECEMBER 1942
ORIGIN: USSR
LENGTH: 4.88M (16FT)
WIDTH: 2.74M (9FT)
ENGINE: 2X 85HP GAZ-203
CREW: 4
ARMOUR: 35MM (FRONT), 16MM (SIDES)
SPEED: 44KM/H (27.3MPH)
PRIMARY WEAPON: 1X 76.2MM ZIS-3 L/41 FIELD GUN
SECONDARY WEAPONS: DEGTYARYOV MACHINE GUN; CREW'S PERSONAL ARMS

76MM GUN

By 1942 the Soviets were taking the full brunt of the Nazi onslaught on the Eastern Front. The mass-produced T-34 tanks were effective but something more was needed to tilt the war in their favour. The decision was made to begin the production of so-called 'tank destroyers' that would halt the Panzer advance.

The 76.2mm gun fared well against the Panzer III and IV but as stronger German tanks rolled onto the front, the SU-76M was reduced to an infantry support vehicle, as it could not penetrate the thick armour of the Tiger and Panther tanks. Some models of the SU-76 could also have anti-aircraft guns mounted instead and there was also a short-lived prototype with a 57mm armament as the Red Army tinkered with the tank-destroyer formula.

The 76.2mm gun was effective against the earlier Panzers but found it very difficult to puncture a Tiger's thick armour

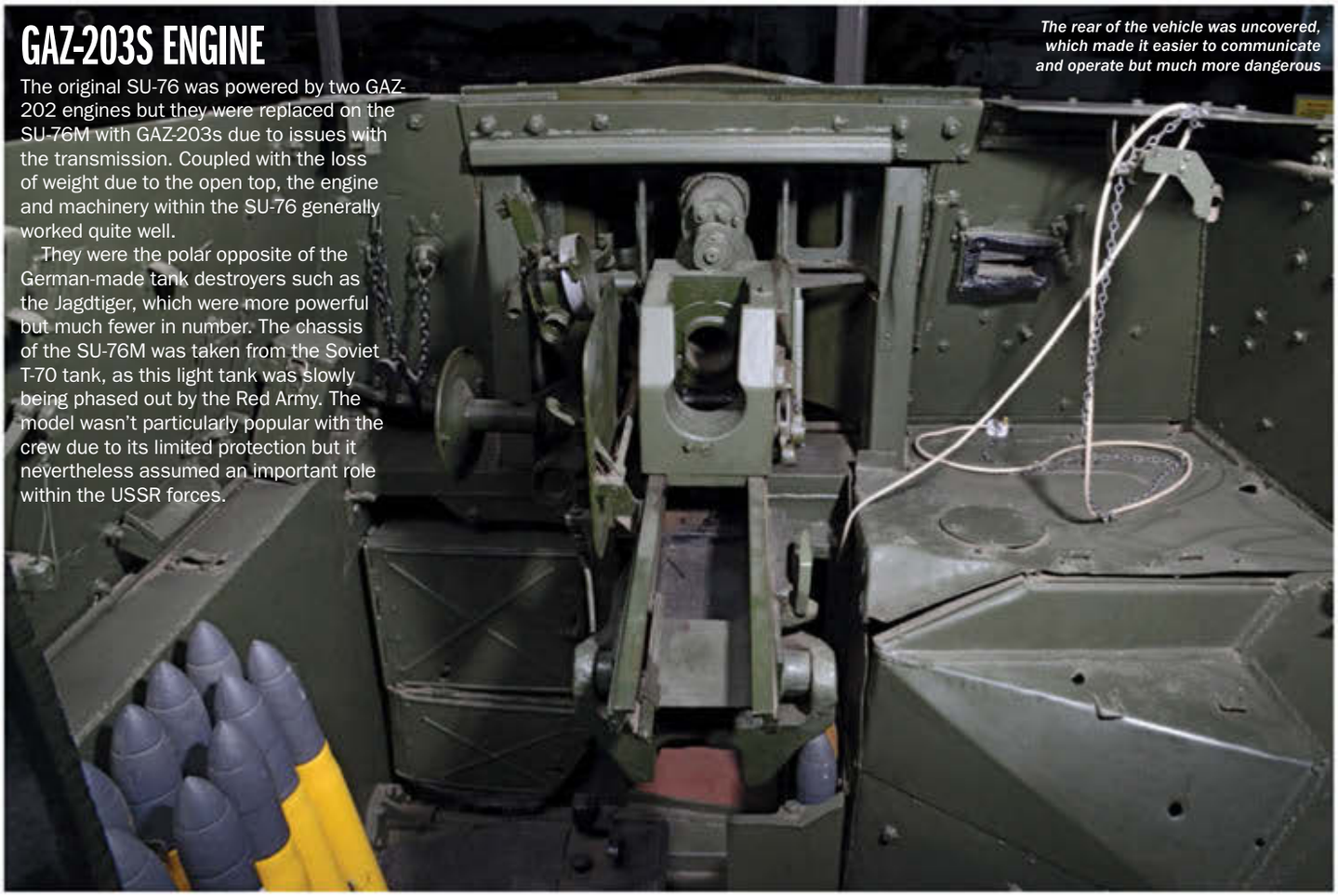
The ZiS-3 76.2mm was taken from a Russian field gun and attached to a tank chassis

"THE MOST EFFECTIVE TACTIC WOULD BE TO FLANK A PANZER AND CATCH IT OFF GUARD WITH A STRIKE ON THE WEAKER ARMOUR"

GAZ-203S ENGINE

The original SU-76 was powered by two GAZ-202 engines but they were replaced on the SU-76M with GAZ-203s due to issues with the transmission. Coupled with the loss of weight due to the open top, the engine and machinery within the SU-76 generally worked quite well.

They were the polar opposite of the German-made tank destroyers such as the Jagdtiger, which were more powerful but much fewer in number. The chassis of the SU-76M was taken from the Soviet T-70 tank, as this light tank was slowly being phased out by the Red Army. The model wasn't particularly popular with the crew due to its limited protection but it nevertheless assumed an important role within the USSR forces.



The rear of the vehicle was uncovered, which made it easier to communicate and operate but much more dangerous

35MM ARMOUR

The tank killer's game was based on using camouflage and cover rather than going in all guns blazing. The most effective tactic would be to flank a Panzer and catch it off guard with a strike on the weaker armour at the side or rear. If the SU-76M was caught out in the open, it had 35mm armour on its front and 16mm on its sides. This armour was strengthened on the later SU-76Ms that served in the final months of the Second World War and the Korean War. Unlike a tank, the SU-76 was open at the back to allow the gunner and loader to communicate with other vehicles with hand signals. The downside to this was the lack of protection to the crew. This was rectified on several later designs but they never made it past the prototype stage.

The armour of the SU-76M wasn't famed for its thickness and could be pierced by machine gun fire

THE OTHER TANK KILLERS

THE SU-76M WASN'T THE ONLY VEHICLE ON THE BATTLEFIELD THAT WAS DESIGNED TO ELIMINATE TANKS

STURMGESCHÜTZ III GERMAN

Based on the body of a Panzer III, the StuG III was the German equivalent of the SU-76M. It was employed in a defensive role and its 75mm gun could penetrate 85mm thick tank armour from over 1,000m (3,280ft) away.

M10 AMERICAN

The M10s were based on Sherman M4A2 tanks and were employed in Western Europe in specialised tank destroyer battalions. The M10s had thick 37mm armour and were implemented into the Danish, Dutch and Belgian armies during the struggle against the Wehrmacht.

ARCHER BRITISH

An unusual design, the Archer was born out of the British army's desire to create a mobile transport for its 17 pounder anti-tank gun. Despite being unable to fire when moving, the Archers proved successful and were in use until the Fifties.

JAGDTIGER GERMAN

The heaviest tank killer of then all, the Jagdtiger was produced far too late to have any affect on the war. Only 80 of these 70-ton machines were made and they were constantly dogged with engine and fuel issues.

THE SU-76M IN THE FIELD

TANK MUSEUM WARDEN TOM MOORCROFT ON THE FAMOUS RUSSIAN TANK KILLER

WHAT ROLE DID THE VEHICLE HAVE WHEN DEPLOYED ON THE BATTLEFIELD?

It was mainly used for heavy suppressing fire and pursuing tanks. It is basically a mobile artillery gun. The difference between it and a tank is that a tank has a turret.

HOW DID IT STAND UP AGAINST THE FORMIDABLE GERMAN TIGER TANKS?

The SU-76, as the name says, has the smaller 76mm gun. It was later upgraded to an 85mm gun to combat the Tiger and Tiger II whose armour was far too thick to penetrate. Ideally this vehicle would be used against smaller tanks such as the Panzer III and Panzer IV.

WHAT WERE THE CONDITIONS LIKE INSIDE?

Pretty much the same as any tank but it's open at the back and is essentially a convertible! The loader and gunner would be on the rear while the driver sat below the gun at the front. It's based on the T-34 but it is actually quite dissimilar with its open roof.

WHAT TANK WAS IT MOST EFFECTIVE AGAINST?

Only the Germans and the Russians really used tank destroyers, as the UK and the USA preferred just using tanks. When used with tanks and machine guns, it could hold off an enemy advance. Even when enemy tanks weren't spotted, the SU-76 could be very effective as a camouflaged artillery gun against infantry before the main armoured column arrived.

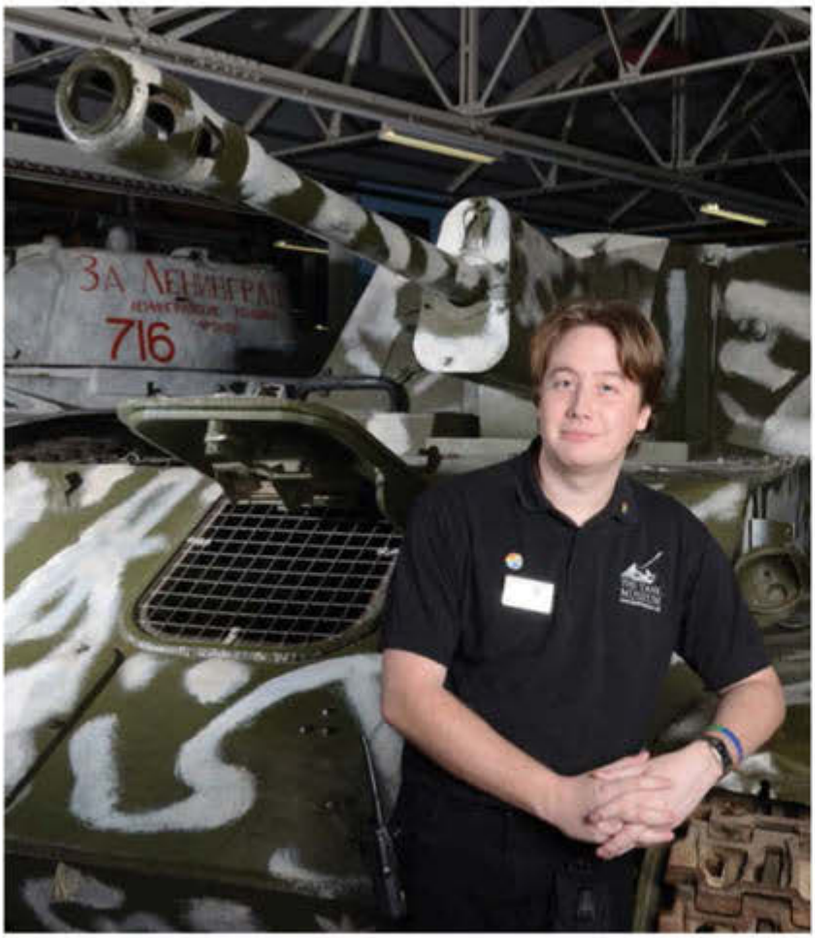
DID IT HAVE ANY FLAWS?

The problem with a tank destroyer is the limited movement of the gun, which can only aim up and down and not 360 degrees. If you want to fire left and right, you have to move the whole vehicle. When enemy convoys split up, an SU-76 could be easily outflanked. However, this vehicle is a very good example of Russian mechanical reliability. German tank killers such as the Jagdtiger were so complicated to build, by the time you've made one of them, you've made many SU-76s. They are very crude in their design but you just make as many as you can.

AFTER THE END OF THE KOREAN WAR, DID TANK KILLERS REALLY BECOME OBSOLETE?

Well, that argument has been going on throughout the history of the tank – is the tank really relevant? Personally, if the enemy has tanks, you're always going to need tanks yourself in order to lead a counterattack. In the territory of the Korean War, you can't really use tanks in urban warfare but they are still very effective in open fields as long as you don't get bogged down!

***Below:** The rear of the SU-76M was open to the elements, giving the gunner and loader little to no protection*



***Below:** A wrecked North Korean SU-76M captured and examined by the US Army in the Korean War*

The SU-76M wasn't overly popular with its crews and was called 'Suka' meaning 'The Bitch'

TANK DESTROYERS IN MODERN WARFARE

ARE TANK KILLERS RELEVANT IN TODAY'S CONFLICTS?

After the Second World War, Nazi Germany went through a mass disarmament process and the USSR sheltered behind its impenetrable Iron Curtain. So, what happened to the tank destroyer? The SU-76M model was sold in large swathes to North Korea but as tanks got stronger and wars became more covert in nature, the role of the tank destroyer began to diminish.

Some still remain today, although they look different to the World War Two vintage. Rather than installing field guns, missile launchers are now a much more effective way of laying waste to armoured tanks on the battlefield. Although lightly armoured, the missile's guided systems allow the tank destroyer to strike from a reasonable distance.

"AS TANKS GOT STRONGER AND WARS BECAME MORE COVERT IN NATURE, THE ROLE OF THE TANK DESTROYER BEGAN TO DIMINISH"

Taking its lead from the US M-113, the Norwegian Model-142 uses a TOW2 guided missile system to blast tanks out of the battlefield

This British tank destroyer was introduced in 1975 and saw service in the Gulf War. Its Swingfire missiles have a range of 4,000m (13,120ft)

Breaking away from the traditional look, this was the first guided missile anti-tank vehicle to be produced when it made its debut in 1962

Though highly effective during their heyday, tank destroyers have largely been phased out of modern armies

With all the hatches closed, visibility from the SU-76M was limited

The Tank Museum; Alamy; Getty

A DAY IN THE LIFE OF A TANK DESTROYER CREW

WHAT WAS IT LIKE TO SPEND 24 HOURS WITH A RED ARMY TANK KILLER SQUAD?

With the might of the German Armoured Division racing east, the life of a Soviet tank crew was a daunting one. The crew would be composed of 3 or 4 people: a driver, a gunner, a loader and occasionally an extra pair of hands to help with the running of the vehicle. As the rear of the SU-76M was uncovered, both the loader and the gunner were open to the worst of the Russian winter and were unprotected from gunfire. The only good news about an uncovered rear was that the blast radius from a German Panzerschreck would not be as severe. The mobility of the vehicle was key to avoid as much fire as possible as well as getting in close and getting a better shot at the enemy Panzers. Long-distance shots wouldn't have penetrated the armour plus a shot on the side or the rear of a Tiger or Panther would do much more damage. The fuel capacity was around 500 litres (101 gallons) of fuel so the tank destroyer could stay in action for a good amount of time. As well as battlefields like Kursk, the SU-76M was useful in urban environments as the Red Army pursued the Wehrmacht through the cities of Eastern Europe. The 76.2mm field gun could blast through buildings and strongholds while the open rear allowed the crew to hop off and introduce the enemy to the full brunt of the PPSH-41 submachine gun. Overall, the SU-76M was an integral feature of the Eastern Front for the Allies. The vehicle revitalised what was a redundant tank chassis and was immensely useful to the Red Army in what they knew as the 'Great Patriotic War'.

A SU-76M crew consults a map and discusses tactics on their advance through Hungary in the Second World War

CHARTING THE EVOLUTION OF SELF-PROPELLED ANTI-TANK WEAPONS

WHERE DID THE USSR GO AFTER THE SU-76M?

After the Second World War, Nazi Germany went through a mass disarmament process and the USSR sheltered behind its impenetrable Iron Curtain. So, what happened to the tank destroyer? The SU-76M model was sold in large swathes to North Korea but as tanks got stronger and wars became more covert in nature, the role of the tank destroyer began to diminish.

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STURMGESCHÜTZ III GERMAN

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SU-100

Even the SU-85 couldn't quite puncture the armour of the mighty Tigers so yet another upgrade was produced with a 100mm anti-tank gun. They came into use in late 1944 and were part of the final push into Germany.

SU-152

Utilising a huge 152mm gun, the SU-152 was essentially a howitzer placed on top of a KV-1 heavy tank. It had the potential to knock out the strongest enemy tanks and was so powerful it was used against fortifications.

ASU-85

After the war, the tank destroyer morphed into what is known as a self-propelled gun. The ASU-85 was one such development, and has been replaced by new models such as the BMD-1 and BTR-D, which is still used today.

SU-76 VARIATIONS

THE SU-76M WAS SO POPULAR THAT IT CAME IN A VARIETY OF FORMS AND EVOLUTIONS DURING ITS LIFESPAN

OSU-76

This experimental version of the SU-76M was modeled on a T-60 tank rather than a T-70 but never made it off the Red Army's production line.

SU-76

Building on the good work made by the OSU-76, this version was based on a T-70 tank and was the precursor to the SU-76M.

SU-76B

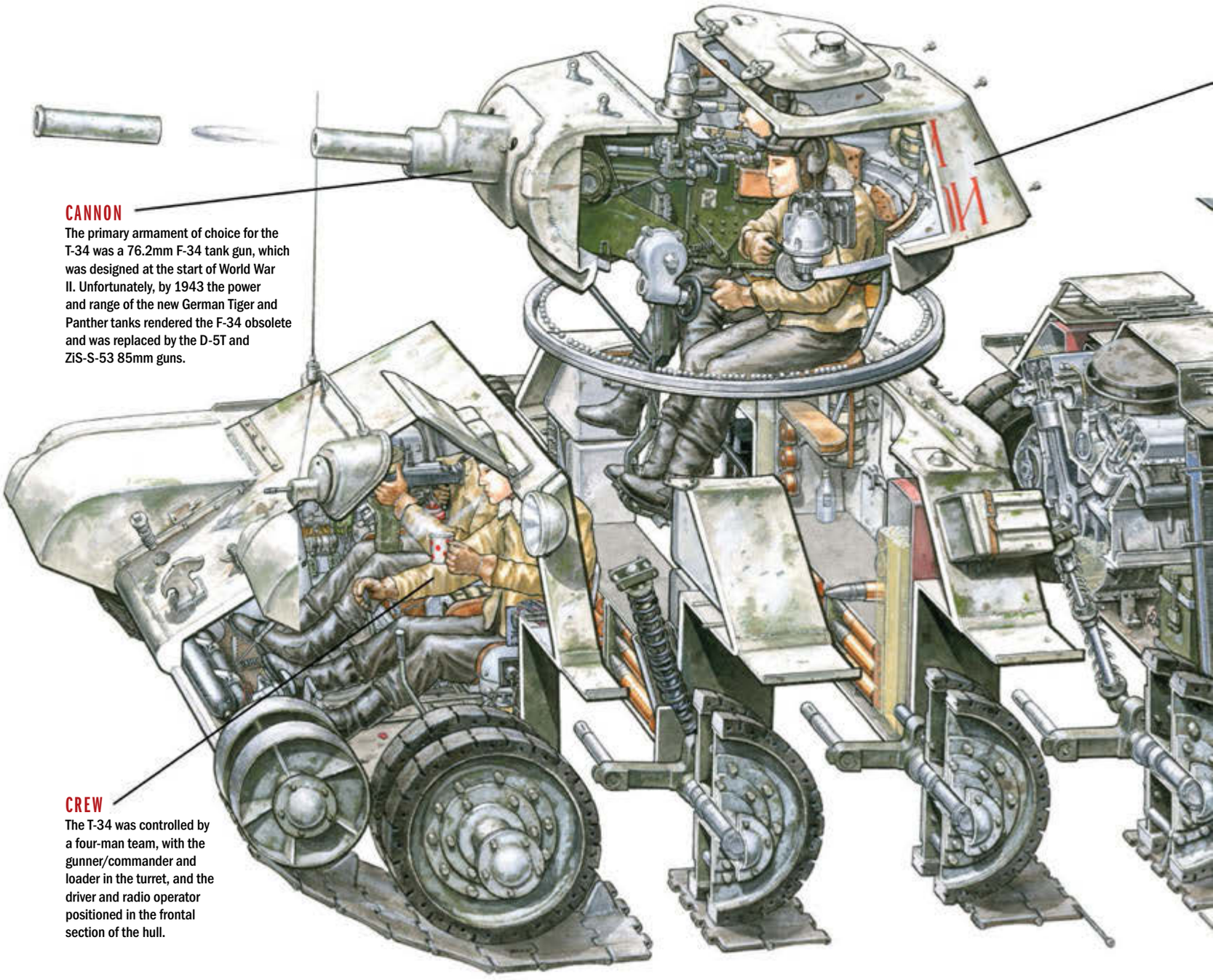
An upgrade on the main model, only a few of these were produced. This tank killer gave the driver and gunner more protection with a fully enclosed crew compartment.

SU-76I

Over 1,000 of these hybrid versions were created during the war from converted StuG III captured from the Wehrmacht.

As the turret couldn't move 360 degrees, SU-76M's were used in a mobile artillery gun role

"THE 76.2MM FIELD GUN COULD BLAST THROUGH BUILDINGS AND STRONGHOLDS, WHILE THE OPEN REAR ALLOWED RAPID CREW DEPLOYMENT"



CANNON
The primary armament of choice for the T-34 was a 76.2mm F-34 tank gun, which was designed at the start of World War II. Unfortunately, by 1943 the power and range of the new German Tiger and Panther tanks rendered the F-34 obsolete and was replaced by the D-5T and ZiS-S-53 85mm guns.

CREW
The T-34 was controlled by a four-man team, with the gunner/commander and loader in the turret, and the driver and radio operator positioned in the frontal section of the hull.

T-34 TANK

Often credited as the most effective and influential tank of World War II, the T-34 brought a solid mix of speed, agility and stopping power to the theatre of war

Among the most popular vehicles of World War II, the Soviet Union's T-34 medium tank is considered by military historians to be one of the most important and influential tanks ever built.

Evolving out of the BT series of fast tanks (Soviet cavalry tanks with thin armour and high mobility), the T-34 at its introduction was the first tank to sport a complete balance between firepower, mobility, protection and longevity – something that modern tanks now take for granted. Further, it was an especially refined and simple design that allowed for costs (135,000 rubles) and production time frames to be kept low, meaning that many tanks could be produced in very little time and allow Russia to mitigate its higher-than-average losses quickly and cheaply. Indeed, this became a very important factor towards the end of the war when the superior – but hard and expensive to manufacture – German Tiger and Panther tanks could not be replaced fast enough.

The T-34 was fitted with a good balance of weaponry, sporting a 76.2mm F-34 tank gun – ideal for taking down medium and light armoured enemy vehicles – and twin 7.62mm DT machine guns, perfect against unarmoured targets and to suppress advancing soldiers. Its armour also offered a great balance between protection and weight, with up to 63mm of armour plating standing between its crew and the shells and bullets of the enemy. This meant that only the largest of enemy cannons – such as the 88mm beast fitted to the German Tiger tank – could breach its hull or turret and, considering its high top speed of 33mph, this was only possible if it became entrenched or caught unawares. By keeping the armour thickness to a medium level though, the total

TURRET

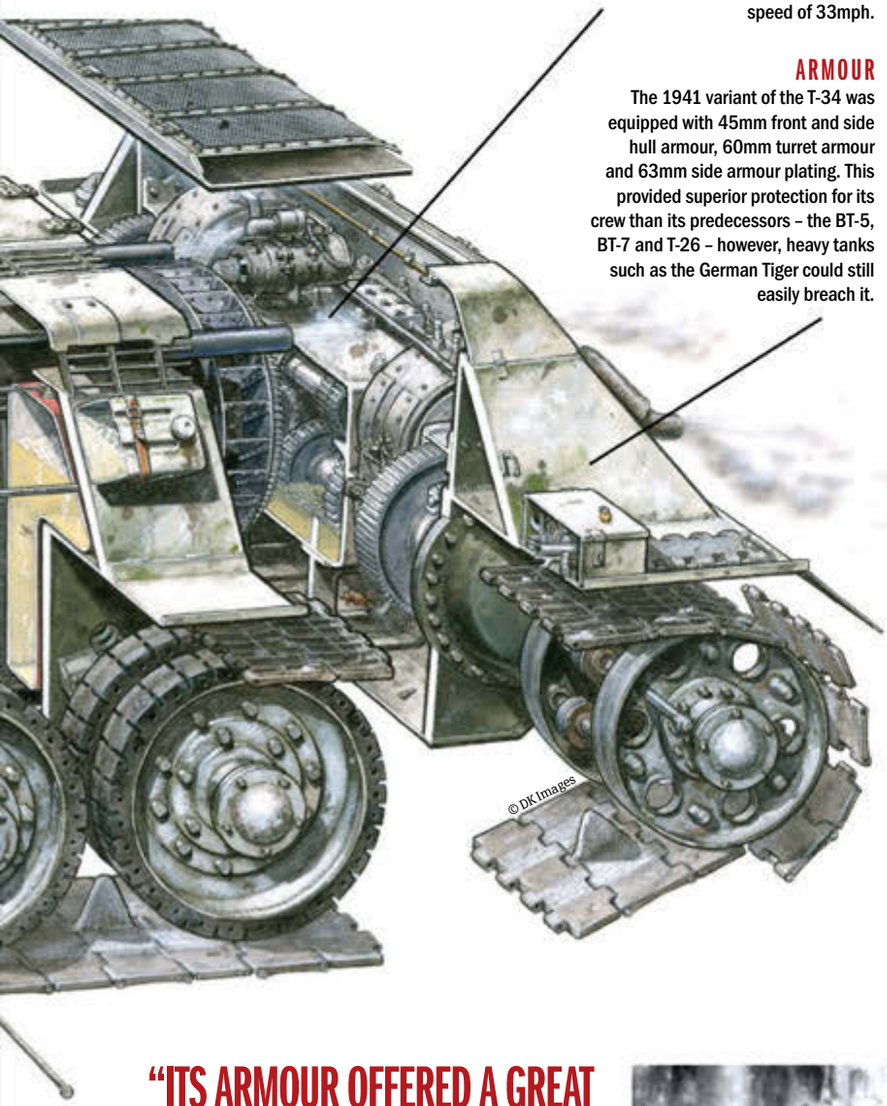
The T-34 used a two-man turret crew system where the tank's commander also served as the gunner. This was common in Soviet tank designs during World War II, despite three-man turret crews proving superior in the field. Later models of the T-34 expanded the turret ring to allow for three-man turret crews.

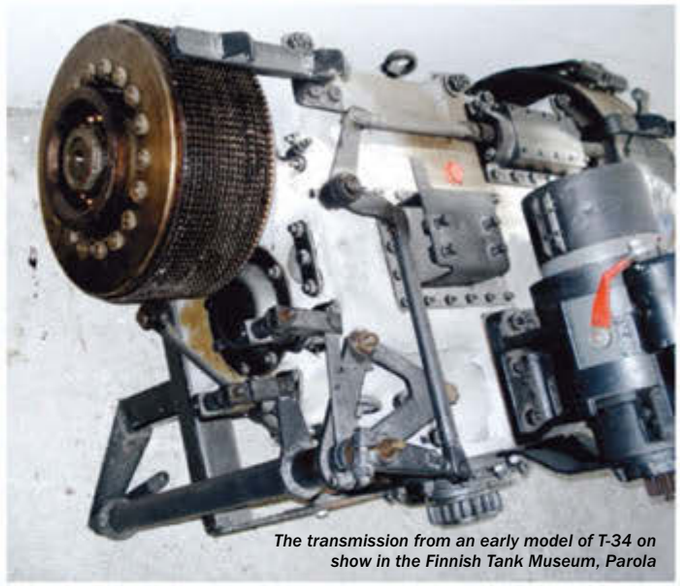
ENGINE

The T-34 used a 12-cylinder Gaz diesel V-2 engine, which was capable of churning out 500hp. Due to the tank's relatively light weight compared to its heavier contemporaries, this gave the T-34 a power to weight ratio of 17.5 horsepower per ton and, as a result, a good top speed of 33mph.

ARMOUR

The 1941 variant of the T-34 was equipped with 45mm front and side hull armour, 60mm turret armour and 63mm side armour plating. This provided superior protection for its crew than its predecessors – the BT-5, BT-7 and T-26 – however, heavy tanks such as the German Tiger could still easily breach it.





The transmission from an early model of T-34 on show in the Finnish Tank Museum, Parola

T-34 TANK

WEIGHT 26.5 TONS
LENGTH 6.68M (21.9FT)
WIDTH 3.00M (9.8FT)
HEIGHT 2.45M (8.0FT)
ENGINE 12-CYLINDER GAZ DIESEL MODEL V-2 500HP (370KW)
MAX RANGE 250 MILES (400KM)
MAX SPEED 33MPH (53KM/H)
CREW 4

The interior of a T-34-85 variant

"ITS ARMOUR OFFERED A GREAT BALANCE BETWEEN PROTECTION AND WEIGHT, WITH UP TO 63MM OF ARMOUR PLATING BETWEEN ITS CREW AND THE ENEMY"

weight of the T-34 was kept down to 26 tons, under half that of the Tiger and allowing the T-34 unrivalled dynamism in the field.

Historically, the T-34 will be remembered as the vehicle that swept German forces from Russia, advancing from Stalingrad to Berlin in 1945. However, its usage continued right up to 1958, when it was replaced by its successor the T-54. Despite its official retirement though, the T-34 has continued to be used in Third World militaries right up to the present day and has also found itself bought and operated by both private collectors and military museums.

A T-34 in front of the Brandenburg Gate in Berlin, 1945

WILLYS JEEP

The most iconic light transport vehicle of World War II, the Willys jeep was versatile, manoeuvrable and fast over uneven terrain

The first and most distinctive jeep ever built, the Willys jeep was designed in 1940 as part of a competition to provide the US Army with a new light transport vehicle for the impending World War II. It dictated light transport vehicle design for decades to come, only being phased out in the late-Seventies. Light, adaptable and highly manoeuvrable, the Willys jeep in its various forms (MA, MB and post-war M38/M606) allowed allied forces to transport troops, munitions and injured soldiers to and from the front line quickly and efficiently.

Central to its effectiveness was its L134 2.2-litre engine, capable of producing 60hp at 4,000rpm. This granted the lightweight Willys (1,040kg) a top speed of 45mph and earned the engine the nickname of 'Go Devil' by allied troops. The engine was controlled by a Warner T-84J three-speed synchromesh transmission, which provided three forward gears and one in reverse in a four-wheel drive setup, allowing for the jeep to easily traverse road, desert, scrub and jungle terrain.

The engine was forward-mounted to a lightweight steel chassis. This featured a foldable windscreen, slatted iron grille (later additions a steel grated grille), and front frame cross-member for rigidity and damage mitigation. The chassis sat on top of a compact 80-inch wheelbase that was installed with leaf springs and shock absorbers (excellent for passage over bumpy ground), as well as fully hydraulic brakes on each of its four wheels (granting fantastic stopping power).

The Willys jeep was also prized for its high adaptability, with various different vehicle setups possible dependent on the mission role in question. Troop transport maximised passenger space, with extra seats at the rear, while as a mobile medical centre the rear seats could be removed to make way for stretchers, medicines and operating equipment. The jeep could also be installed with various weapons platforms, including a rear-mounted 37mm cannon and array of different Browning M1917 machine guns.

While the Willys jeep was subsequently upgraded post-war with a larger engine (the F4-134 Hurricane), more durable transmission (Warner T-90) and a range of advanced instrumentation and electronics, it was eventually replaced in the late-Seventies and early-Eighties as larger, more armoured vehicles like the Humvee became the military's primary troop transporters.

"THE WILLYS JEEP WAS PRIZED FOR ITS HIGH ADAPTABILITY, WITH VARIOUS DIFFERENT SETUPS POSSIBLE DEPENDENT ON MISSION ROLE"

The Willys' versatility was its greatest asset, allowing it to be used in a variety of roles

Willys could transport the injured on stretchers as the rear seats were removable

WW II soldiers march alongside a Willys jeep towing a trailer

Willys MA jeep undergoing desert trials

INSTRUMENTATION

The Willys MB jeep was fitted with a 0-60 mph speedometer, 0-220 Fahrenheit temperature gauge, oil pressure monitor and map light.

UNDER THE HOOD

THE COMPONENTS THAT MADE UP THIS EFFECTIVE WAR VEHICLE

CHASSIS

The jeep's chassis was lightweight and constructed from steel. It featured a foldable windscreen, stamped forward grille and U-shaped cross-member.

WHEELBASE

The Willys MB wheelbase was 80 inches and featured leaf springs and shock absorbers, full hydraulic breaks on each wheel and a handbrake assembly at the rear of the transfer case.

TRANSMISSION

The MB sported a Warner T-84J three-speed synchromesh transmission, with three forward gears of increasing speed and one in reverse. The MB was predominantly four-wheel drive.

ENGINE

The Willys L134 engine powered the MB and was nicknamed the 'Go Devil', due to its power. The engine was 2.2 litres in size, could produce 60hp at 4,000rpm and featured an in-built oil filter, oil mesh, throat carburettor and manual choke.

The engine bay of the Willys MB, clearly showing its L134, 'Go Devil' engine

WILLYS JEEP

CREW 3
CAPACITY 5
WEIGHT 1,040 KG (2,293LB)
LENGTH 3.3 METRES (131 INCHES)
WIDTH 1.57 METRES (62 INCHES)
HEIGHT 1.83 METRES (72 INCHES)
ENGINE 4-CYLINDER, 2.2-LITRE L134 PETROL
MAX HORSEPOWER 60HP @ 4,000RPM
MAX SPEED 45MPH (72.4KPH)
TRANSMISSION WARNER T-84J 3-SPEED SYCHROMESH
PRODUCED 640,000

A Willys jeep of the US 3rd Infantry, Newfoundland, 1942. Note the large 37mm cannon and M1917 Browning machine gun

A jack of all trades, the Humvee can be configured to perform many roles

A snorkel and raised exhaust make the Humvee a great amphibious vehicle

HUMVEE

The high-mobility multipurpose wheeled vehicle (HMMWV) roars off the production line ready for action

Designed to replace several outdated American military vehicles, the high-mobility multipurpose wheeled vehicle, or Humvee, has been in production since 1985. Originally intended as a light utility vehicle, there have been more than 20 variants of this highly customisable, modular platform. Serving over 40 nations, around 200,000 Humvees have been built to date. Able to carry and deploy almost anything, from fully armed troops to anti-aircraft missiles, the Humvee is an open-topped scout vehicle, an armoured personnel carrier, ambulance, a TOW missile launcher, a communication centre, a heavy machine gun platform and whatever else the situation requires.

The latest models are unrivalled in their off-road capability, and are based around a 6.5-litre (1.7-gallon) V8 Turbo diesel engine which produces 142 kilowatts (190 brake horsepower) and 515 Newtons per metre (380 pounds force per foot) of torque. This power is sent to all four wheels through an electronically controlled four-speed automatic gearbox, using a series of differentials. The drivetrain is rather unconventional as the wheels themselves contain portal-geared hubs, which not only double the torque generated, but due to the offset driveshaft inputs, enable the vehicle's ground clearance to be significantly higher than a regular centre axle would allow. This innovative drivetrain, coupled with independent suspension and 94-centimetre (37-inch) tyres, allow the Humvee to travel at 113 kilometres (70 miles) per hour or to climb slopes of 60 per cent – though some Humvees have been seen to climb near-vertical walls! The internal environment is fully air conditioned, while a deep-water fording kit allows the vehicle to cross rivers almost completely submerged. These capabilities, combined with design features such as the sturdy chassis, corrosion resistance plus high commonality and interchangeable parts, enable the Humvee to be flexible, dependable and rugged even in the harshest of environments.

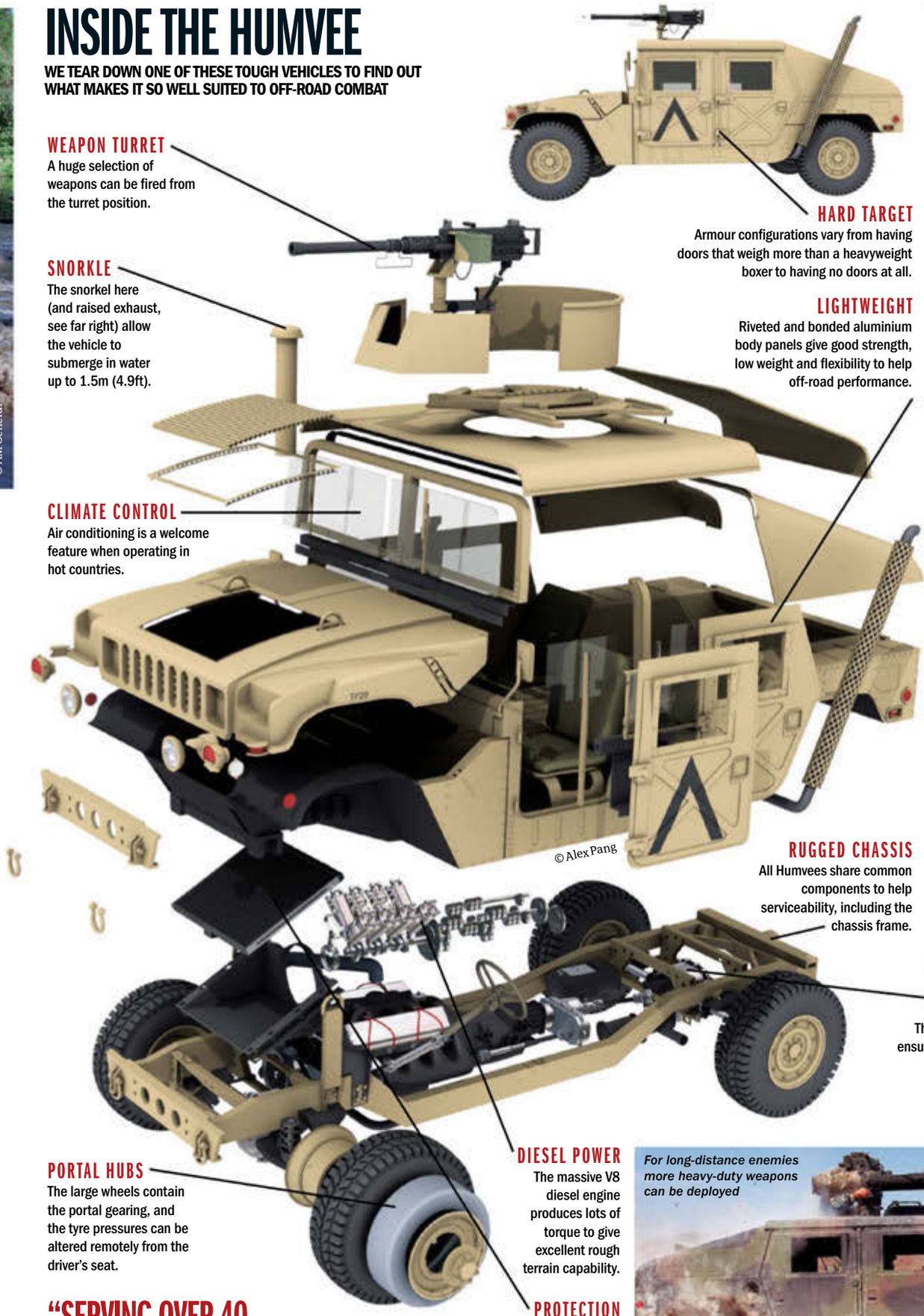
The turret can be fitted with weapons for all kinds of combat situation

ARMOUR OPTIONS

Since the Humvee was first introduced, soldiers have demanded increasingly more protection from it. Early versions had fabric doors and no roof, but the demands of conflicts in Somalia, Iraq and Afghanistan demonstrated the need for improved armour. Many improvised solutions have been tried in the field in recent years, including sandbags and welding scrap metal to the chassis. However, heavily armoured versions are now available from the factory, as are retrofit kits, which include under-body plates, heavy doors, armoured seats, weapon shields and numerous other additions. The latest iterations offer the crew protection from assault rifle bullets, some air-burst artillery, and up to 5.4 kilograms (12 pounds) of explosives, thanks to thick steel armour, energy-absorbing coatings and mounting, and reinforced glass. All of this comes at a price, though, with many Humvees carrying 907-1,814 kilograms (2,000-4,000 pounds) of armour, which can only be taken in place of cargo and equipment. Work is now underway to make the Humvee more resistant to buried explosives, as in its current state, the large flat floor is not effective against these.

INSIDE THE HUMVEE

WE TEAR DOWN ONE OF THESE TOUGH VEHICLES TO FIND OUT WHAT MAKES IT SO WELL SUITED TO OFF-ROAD COMBAT



PACKING A PUNCH

There was always a requirement to arm the Humvee to provide fire support and self-defence, but the variety of weapons it can carry is astonishing. Starting with a choice of general-purpose machine guns, most weapons can be fired manually or fitted to the remotely operated CROWS turret system. The most common weapon choice is the legendary M2 Browning .50 Calibre. However, should there be a need to raze everything in sight to the ground, the gunner can unleash 100 shots per second using the awesome M134 minigun. For even bigger bangs, the 40-millimetre (1.6-inch) grenade machine gun can launch 60 high-explosive grenades per minute. Should an enemy bring a tank to the fight, the Humvee can launch the TOW anti-armour missile from 3.8 kilometres (2.3 miles) away, or in situations requiring a little bit of overkill, the Humvee is designed to tow a Howitzer cannon. The ultimate version, however, has to be the Boeing-developed Avenger, which carries up to eight stinger anti-aircraft missiles, with proposals for additional weapons including a one-kilowatt laser.

"SERVING OVER 40 NATIONS, AROUND 200,000 HUMVEES HAVE BEEN BUILT"

For long-distance enemies more heavy-duty weapons can be deployed

ABRAMS M1 BATTLETANK

The 74-ton, 1,500-horsepower behemoth fires long-range cannons

Imagine driving one of these on your morning commute. The M1 Abrams battletank, used throughout the Eighties and Nineties for both Gulf wars, and still more advanced than any other tank on the planet, is a 74-ton monster of a vehicle that can crash through walls and over almost any terrain it finds itself traversing.

"The design of this tank is what makes it unique from its first inception," says Mike Peck, the director of business development at General Dynamics, the company that designs and manufactures the M1. According to Peck, the M1 uses a "combat platform" suspension with a low-to-the-ground chassis and a contoured body that allows the turret to be nestled down lower than other tanks, making the tank about three feet lower to the ground than similar vehicles. In the mid-Nineties, the M1 was updated with all-digital components, further increasing its battlefield capabilities. Peck says it actually has more electronics than an F16 fighter.

Kevin Benson, a retired Lt Colonel who commanded entire battalions of M1 tanks, says the main advantage of the M1 is that it can fire 120mm rounds up to 3,000-4,000m whereas other tanks – especially those used by Iraqi forces in Operation Desert Storm – could only fire about 1,500m. In that campaign, US forces would surround the Iraqi tanks, safely out of range of the enemy but well within the range of the M1. Peck says the M1 has a forward-range infrared sensor that works in day or night for long-range shots.

The engine on the M1 is also unique. It uses a turbine engine running at 1,500 horsepower, providing a distinct advantage over its rivals: because the tank has such a high torque in the engine, it is almost unstoppable on the battlefield. "The engine has the most dense horsepower-per-weight ratio we could find," says Peck.

The M1 also has a pulse jet air cleaner in order to remove sand and other hazards and debris, which Peck says has doubled the life of the engine. The tank is also outfitted with a 50 calibre machine gun that can turn 360-degrees, an important aid for urban warfare. As speedy as it is strong, the M1 Abrams cruises at a top speed of 45 miles per hour on paved roads or 35 miles per hour over sand.

The M1's main cannon is capable of inflicting serious damage

ABRAMS M1 IN ACTION

JUST WHAT MAKES THE ABRAMS M1 SO FORMIDABLE?

LONG-RANGE, 120MM ROUNDS

Benson says a key feature on the M1 is that it fires 120mm rounds up to 4,000m, a decided advantage on the battlefield. The rounds are made of high-density steel, travel one mile per second, and weigh around 30 pounds. "It's like firing a big nail," says Benson.

HEAVY ARMOUR PROTECTION

Both Peck and Benson said another key advantage is that the tank is heavily armoured. Peck says he has never seen a tank that came back for repairs with any noticeable dents; many have fought in multiple campaigns and are still in prime condition.

HIGH-TORQUE ENGINE

According to Benson, the high-torque engine on the M1 tank is extremely advanced: it uses a form of jet fuel to operate and produces so much energy that, even at 74 tons, the tank can reach speeds approaching 45 miles per hour on the road.

"IN THE MID-NINETIES, THE M1 WAS UPDATED WITH ALL-DIGITAL COMPONENTS, FURTHER INCREASING ITS CAPABILITIES"

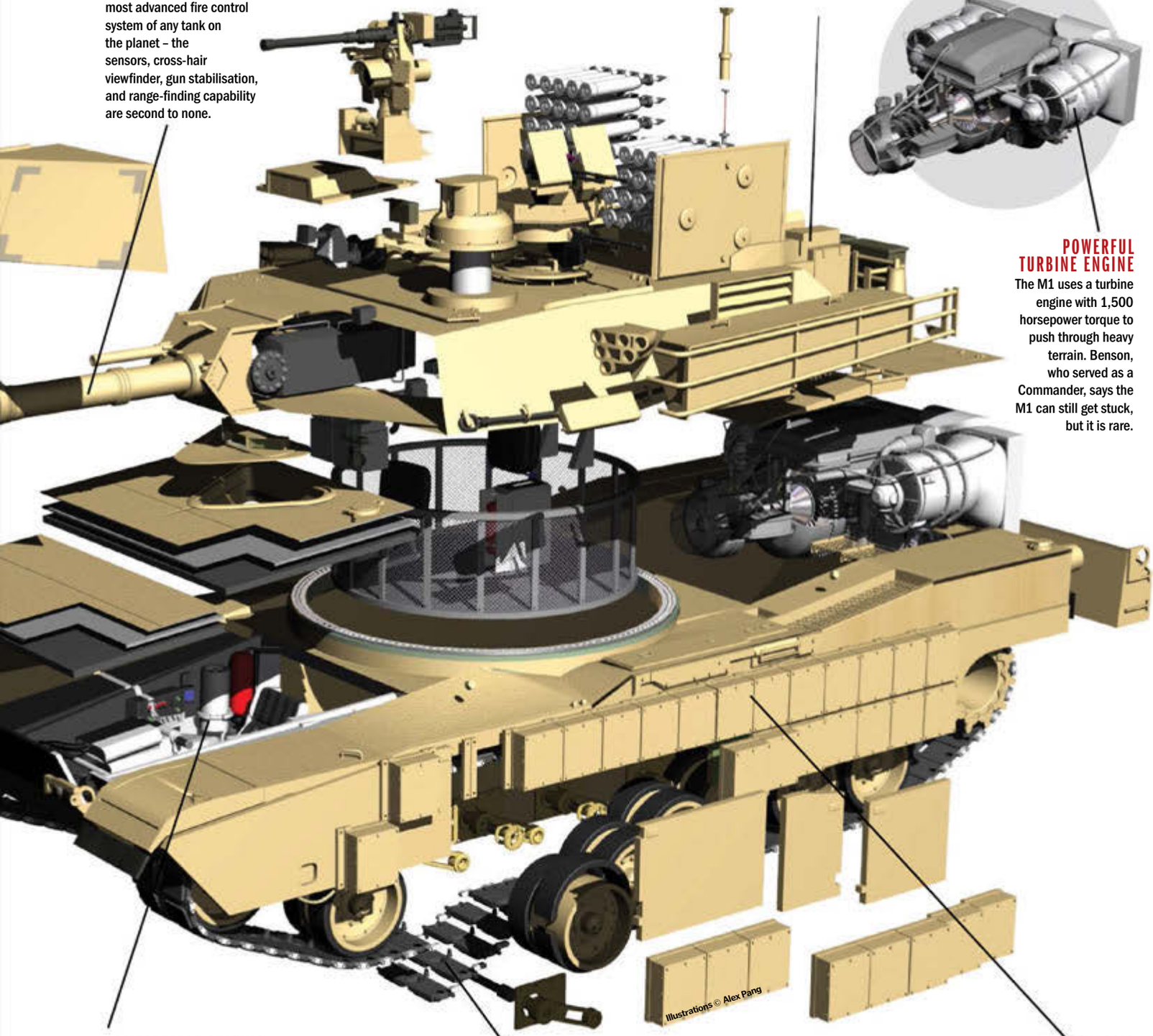
A US tank provides suppressive counter fire in Fallujah, Iraq

UNDER THE HOOD OF THE ABRAMS M1

FIND OUT WHAT MAKES THE ABRAMS M1 THE MOST ADVANCED BATTLE TANK ON THE PLANET

FIRE CONTROL SYSTEM

Benson says the M1 has the most advanced fire control system of any tank on the planet – the sensors, cross-hair viewfinder, gun stabilisation, and range-finding capability are second to none.



POWERFUL TURBINE ENGINE

The M1 uses a turbine engine with 1,500 horsepower torque to push through heavy terrain. Benson, who served as a Commander, says the M1 can still get stuck, but it is rare.

COMFORTABLE SEATING

The M1 drives like a car – it has a steering wheel and foot pedals, says Benson (some models use levers for forward and back). Peck says he knows of a gunner who sat comfortably during a Baghdad campaign for 75 hours straight.

TWO-TON TRACKS

The heavy tracks that propel the tank are made of a hard rubber with steel pins that hold it all together. Benson says the soldiers in the tank know how to quickly fix any track problems on the battlefield.

CHASSIS

The chassis of the M1 is what makes the tank able to withstand abuse. Peck says M1 tanks can go through a re-build process three or four times, adding new digital components.

SUPER-SMART COMBAT TANKS

A new fleet of futuristic and highly adaptable armoured attack vehicles is looking to revolutionise how conflicts are fought on the 21st-century battlefield

For decades tank design has been held in the vice-like grip of the 'Iron Triangle', a design mantra that states that any tank – in order to succeed on the battlefield – needs to be built on the sturdy columns of firepower, protection and mobility. The perfect tank, it was deemed, would be a seamless combination of these three key qualities – a machine that could withstand a host of armour-piercing shells, transport its crew both quickly and safely across a war-torn battlefield, and then deliver a series of explosive shells into enemy structures and vehicles.

Today's most advanced tanks are testament to the Iron Triangle – just look at the awesome firepower and armour delivered by the M1 Abrams main battle tank – delivering, in varying degrees of success, heavily armed and armoured mobile fortresses capable of levelling city blocks and boosting an army's odds in any conflict they are deployed in.

However, times are changing. The modern 21st-century battlefield differs radically from that experienced in the mid-20th century when much of today's top armour was conceived. The theatre of war in the present is more fluid, fast-moving and interconnected than ever before, demanding armies to react quickly and efficiently to any intelligence gathered to stay on top. In essence, intelligence and adaptability are now central to any armoured fighting vehicle, and these qualities are rapidly reshaping the Iron Triangle into an 'Iron Pentagon' with which any new build must comply if it's to be an out-and-out success.

In this feature we take a close look at three of the most notable armoured fighting vehicles that are being constructed following the Iron Pentagon principle. These mighty machines not only offer bucketloads of armour and smart munitions, but also deliver advanced electronic architectures, near-omniscient sensors, super-fast internet networks, modular structures to adapt to any situation, plus revolutionary propulsion units.

So, strap yourself in and pay attention, as knowledge is power – and boy do these tanks go a long way to prove it!

ASCOD SV: THE SCOUT

The Specialist Vehicle (SV) is the British Army's new, medium-weight armoured fighting vehicle built on General Dynamics' ASCOD platform. The platform is designed to fulfil various roles that are currently handled by one specialised vehicle. As such, the SV is able to undertake all the diverse roles of these traditional vehicles, replacing them and reducing both costs and training timescales.

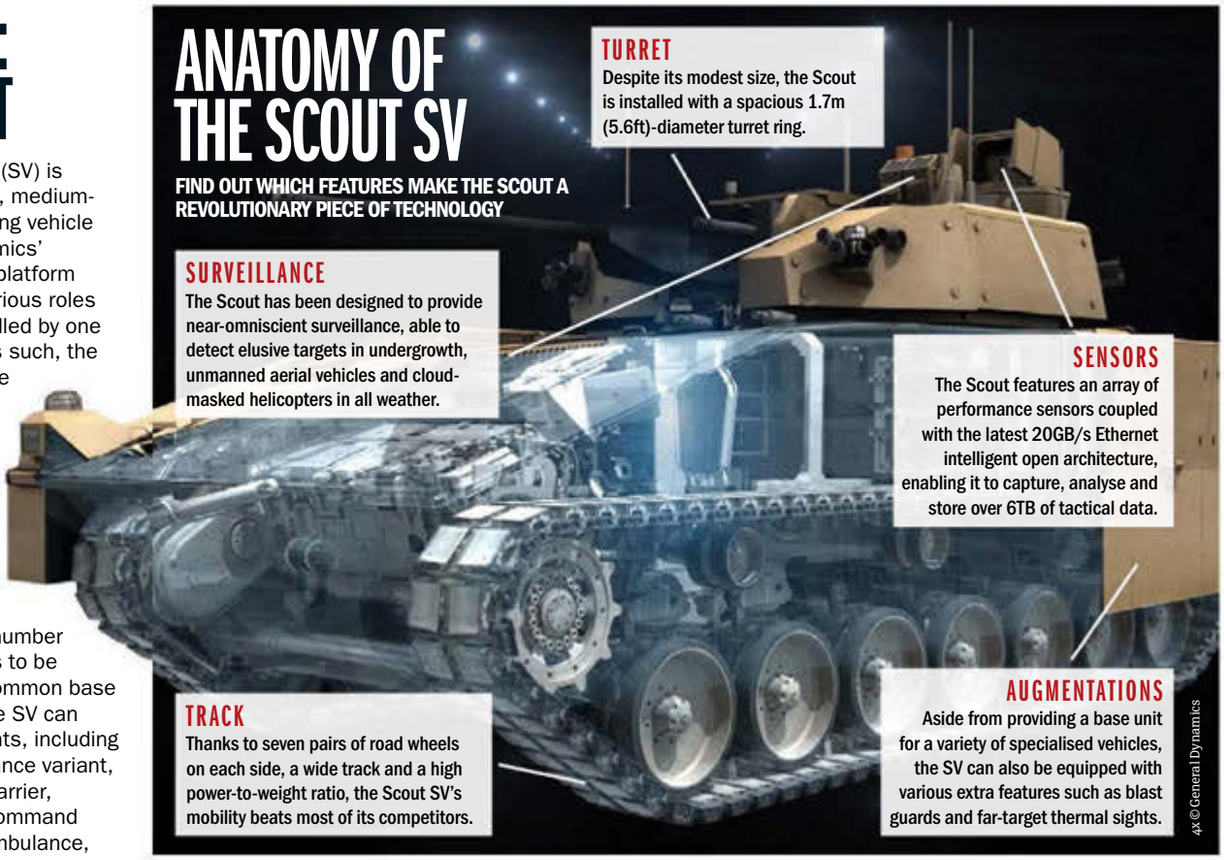
This is possible for two main reasons. The SV's modular architecture allows a number of specialised vehicles to be generated from one common base platform (CBP). So, the SV can deliver some 17 variants, including the Scout reconnaissance variant, armoured personnel carrier, direct fire light tank, command and control vehicle, ambulance, through to recovery and repair engineering vehicles.

Another reason the SV is the 'Swiss Army knife' of the tank world is its integration of an advanced open electronic architecture system. This allows the SV's base vehicle to communicate with any systems unique to its specialised variants, enabling full sensor suite integration and easy control by its operator. It also helps manage the intelligence that can be captured, analysed and stored by the SV, which can be transferred over the latest Ethernet network to the rest of the battlegroup – be they on foot, in other vehicles or at base.

The Scout is installed with an open electronic architecture to accommodate a full sensor array

ANATOMY OF THE SCOUT SV

FIND OUT WHICH FEATURES MAKE THE SCOUT A REVOLUTIONARY PIECE OF TECHNOLOGY



TURRET
Despite its modest size, the Scout is installed with a spacious 1.7m (5.6ft)-diameter turret ring.

SURVEILLANCE
The Scout has been designed to provide near-omniscient surveillance, able to detect elusive targets in undergrowth, unmanned aerial vehicles and cloud-masked helicopters in all weather.

SENSORS
The Scout features an array of performance sensors coupled with the latest 20GB/s Ethernet intelligent open architecture, enabling it to capture, analyse and store over 6TB of tactical data.

TRACK
Thanks to seven pairs of road wheels on each side, a wide track and a high power-to-weight ratio, the Scout SV's mobility beats most of its competitors.

AUGMENTATIONS
Aside from providing a base unit for a variety of specialised vehicles, the SV can also be equipped with various extra features such as blast guards and far-target thermal sights.

4x © General Dynamics

SCOUT SV

WEIGHT 34 TONS SCOUT VARIANT (UP TO 42 TONS WITH UPGRADES)
ENGINE MTU V8 DIESEL
POWER 600KW (805HP)
TOP SPEED 70KM/H (44MPH)
ARMAMENT 1 X 40MM (1.2IN) CTAI CANNON; 1 X 7.6MM (0.3IN) COAXIAL MACHINE GUN
ARMOUR 360° PROTECTION USING LATEST PROVEN MODULAR ARMOUR

"THE SV'S MODULAR ARCHITECTURE ALLOWS A NUMBER OF SPECIALISED VEHICLES TO BE GENERATED OFF THE BACK OF ONE COMMON BASE PLATFORM"

MODULAR MAYHEM

ONE OF THE SV'S MOST IMPRESSIVE QUALITIES IS ITS MODULAR DESIGN, ALLOWING IT TO BE CUSTOMISED EXTENSIVELY

Thanks to its common base platform (CBP) and advanced electronic architecture, SV variants will be able to handle a host of different roles on the battlefield. For example, the SV family offers a light tank, anti-aircraft and missile gun station, repair and recovery vehicle, command and communication vehicle and ambulance among other vehicles. Each of these variations can be outfitted to fulfil roles laid out in the British Ministry of Defence's Future Rapid Effect System (FRES) programme, a project designed to create a large fleet of network-enabled, cross-spectrum armoured fighting vehicles. For example, the final phase of the development will also see a bridge layer and heavy-lifting vehicle developed.

5 Facts about SMART TANKS

FRES
The MOD's Future Rapid Effect System (FRES) project awarded a Specialist Vehicle contract to General Dynamics for the ASCOD AFV in March 2010 – the first of the programme.

GLOBAL APPEAL
The CV90 is already in operation in Denmark, the Netherlands, Norway, Finland, Switzerland and Sweden. Its latest iteration is currently in evaluation in Canada, the US and Poland.

PRIVATE EYES
BAE-Northrop Grumman's new Ground Combat Vehicle uses a hybrid electric drive (HED) for propulsion, delivering a top speed of 70km/h (44mph) as well as enhanced efficiency.

ECONOMY BOOST
By value, 80 per cent of the Scout SV vehicles will be completed in the UK, with 70 per cent of the supply chain companies UK-based, boosting the British defence industry.

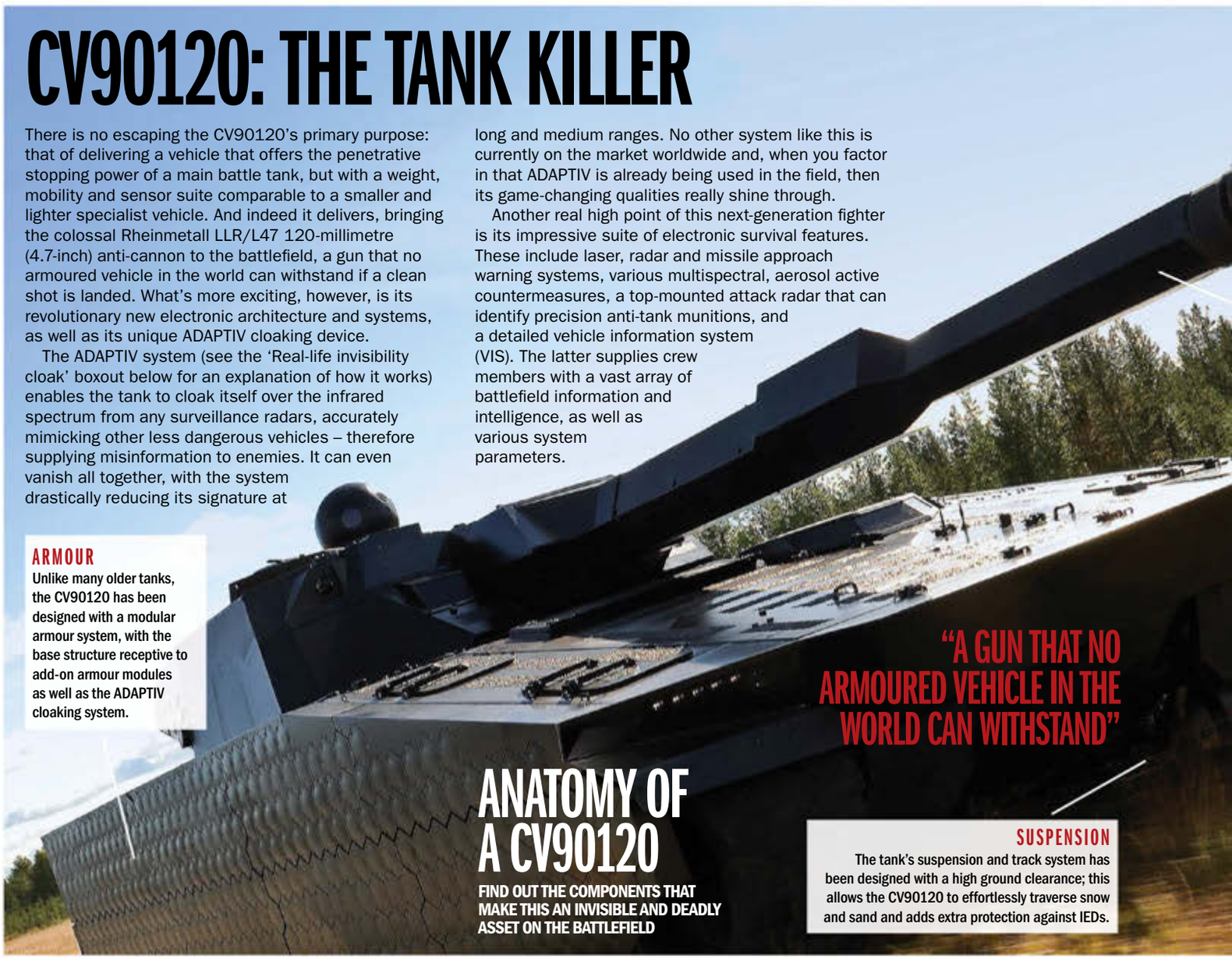
ARMADILLO
The latest build standard for the CV90 is the Armadillo. This has been redesigned to focus on commonality between tank variants and is modular for easy configuration switching.

CV90120: THE TANK KILLER

There is no escaping the CV90120's primary purpose: that of delivering a vehicle that offers the penetrative stopping power of a main battle tank, but with a weight, mobility and sensor suite comparable to a smaller and lighter specialist vehicle. And indeed it delivers, bringing the colossal Rheinmetall LLR/L47 120-millimetre (4.7-inch) anti-cannon to the battlefield, a gun that no armoured vehicle in the world can withstand if a clean shot is landed. What's more exciting, however, is its revolutionary new electronic architecture and systems, as well as its unique ADAPTIV cloaking device.

The ADAPTIV system (see the 'Real-life invisibility cloak' boxout below for an explanation of how it works) enables the tank to cloak itself over the infrared spectrum from any surveillance radars, accurately mimicking other less dangerous vehicles – therefore supplying misinformation to enemies. It can even vanish all together, with the system drastically reducing its signature at long and medium ranges. No other system like this is currently on the market worldwide and, when you factor in that ADAPTIV is already being used in the field, then its game-changing qualities really shine through.

Another real high point of this next-generation fighter is its impressive suite of electronic survival features. These include laser, radar and missile approach warning systems, various multispectral, aerosol active countermeasures, a top-mounted attack radar that can identify precision anti-tank munitions, and a detailed vehicle information system (VIS). The latter supplies crew members with a vast array of battlefield information and intelligence, as well as various system parameters.



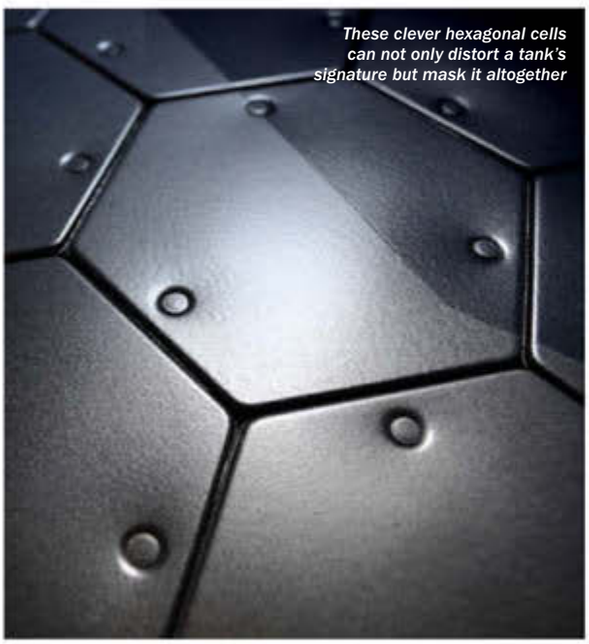
ARMOUR
Unlike many older tanks, the CV90120 has been designed with a modular armour system, with the base structure receptive to add-on armour modules as well as the ADAPTIV cloaking system.

"A GUN THAT NO ARMOURED VEHICLE IN THE WORLD CAN WITHSTAND"

ANATOMY OF A CV90120

FIND OUT THE COMPONENTS THAT MAKE THIS AN INVISIBLE AND DEADLY ASSET ON THE BATTLEFIELD

SUSPENSION
The tank's suspension and track system has been designed with a high ground clearance; this allows the CV90120 to effortlessly traverse snow and sand and adds extra protection against IEDs.



These clever hexagonal cells can not only distort a tank's signature but mask it altogether

THE REAL-LIFE INVISIBILITY CLOAK

THE CV90120 IS HARDWIRED WITH BAE'S ADAPTIV ARMOUR, A REVOLUTIONARY NEW ELECTRICAL CAMOUFLAGE SYSTEM

The ADAPTIV system works by using lightweight, metallic, hexagonal pixels to cover a vehicle's armour, which themselves are powered by the unit's internal electrical system. The pixels are then individually heated and/or cooled using semi-conductors to either remove the tank's heat/radar signature entirely from surveillance radars – making it invisible to the enemy – or mimic the heat signature of another vehicle. As such, the CV90120 tank can quickly and quietly assume the appearance of a 4x4 and have its true threat remain undetected.

Interestingly, the ADAPTIV technology also allows the host vehicle to mimic the textures of other objects, minimising its radar signature even further and enabling it to appear like a range of inanimate natural objects, such as a large rock.

The CV90120's cockpit is installed with a defensive aid suite (DAS), a system that classifies targets and then gives threat warnings

ARMAMENT
The CV90120 comes with a colossal 120mm (4.7in) anti-tank gun – the Rheinmetall 120 LLR/L47 – which enables it to take down any contemporary armoured threat with consummate ease.

MODULES
The latest iteration of the CV90 can be modified in order to become a personnel carrier, an ambulance, a command and control centre, recovery vehicle and mobile mortar-launching platform.

ELECTRONICS
Threat warnings are displayed via a vehicle information system (VIS) in the cockpit, an electronic architecture that also delivers speed corrections to reduce the probability of being hit.

GCV: THE MOBILE FORTRESS

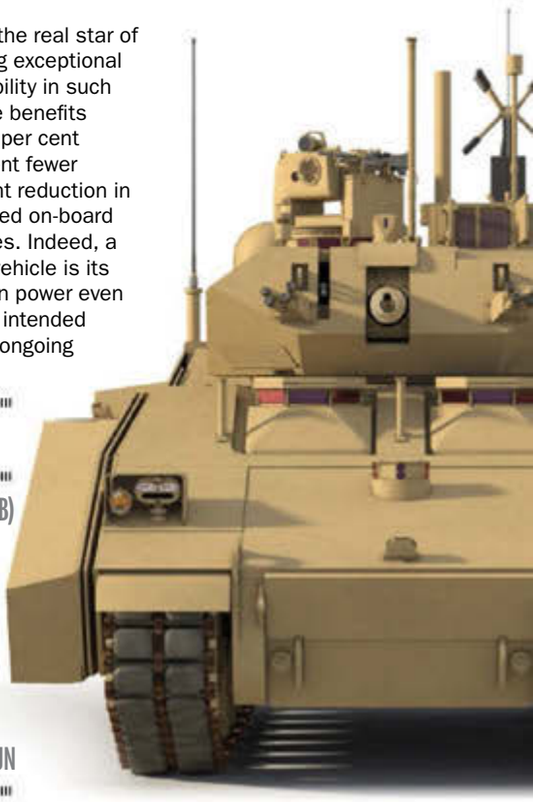
BAE Systems-Northrop Grumman's brand-new Ground Combat Vehicle (GCV) has been designed to provide the right mix of capabilities to adequately tackle the 21st-century battlefield, while also innovating in its delivery of cost-effectiveness over its scheduled 40-year life span. As such, the GCV has been designed to replace existing armoured personnel carriers and light tanks, while also providing a modular common chassis from which future specialist vehicles can be evolved and produced.

The GCV features an adaptive platform built around a space-efficient steel core hull (the vehicle can carry a full squad of nine soldiers), an unmanned turret equipped with a 25-millimetre (one-inch) autocannon and coaxial machine gun, and a cutting-edge hybrid electric drive (HED) propulsion unit. This smart tank can also boast an integrated C4ISR electronic network, including embedded intelligence, surveillance and reconnaissance assets in order to connect personnel to varied information sources – a vital asset in modern warfare.

The propulsion unit is the real star of the show though, offering exceptional force protection and mobility in such a lightweight vehicle. The benefits are marked – read: a 20 per cent saving on fuel, 50 per cent fewer moving parts, 60 per cent reduction in total volume and increased on-board power delivery capabilities. Indeed, a standout feature of the vehicle is its ability to generate its own power even when stationary, a move intended to ready the GCV for the ongoing evolution of its systems.

GCV

WEIGHT 63,500KG (140,000LB)
RANGE 300KM (186MI)
ENGINE HYBRID ELECTRIC DRIVE (HED)
POWER 1,044KW (1,400HP)
TOP SPEED 70KM/H (44MPH)
ARMAMENT 1 X 25MM (1IN) AUTOCANNON; 1 X 7.6MM (0.3IN) COAXIAL MACHINE GUN



ANATOMY OF A GCV

DISCOVER A FEW REASONS WHY THE GROUND COMBAT VEHICLE IS SET TO BE WIDELY ADOPTED BY ARMIES WORLDWIDE

The GCV's use of a hybrid electric engine means it will have a 30-40-year life span

ARMAMENT
Despite its small size, the GCV is equipped with both a 25mm (1in) autocannon and 7.6mm (0.3in) coaxial machine gun, as well as an independent missile launcher operated by the vehicle's commander.

PROPULSION
The GCV's hybrid electric drive engine delivers a 20 per cent reduction in fuel consumption over legacy vehicles, as well as a 50 per cent reduction in moving parts, essentially offering greater reliability.

SUSPENSION
A lightweight and agile in-arm hydropneumatic suspension system consisting of seven road wheels and a 64cm (25in)-wide track delivers excellent mobility across difficult terrain.

SEA

© BAE Systems

NEXT-GEN BATTLESHIPS

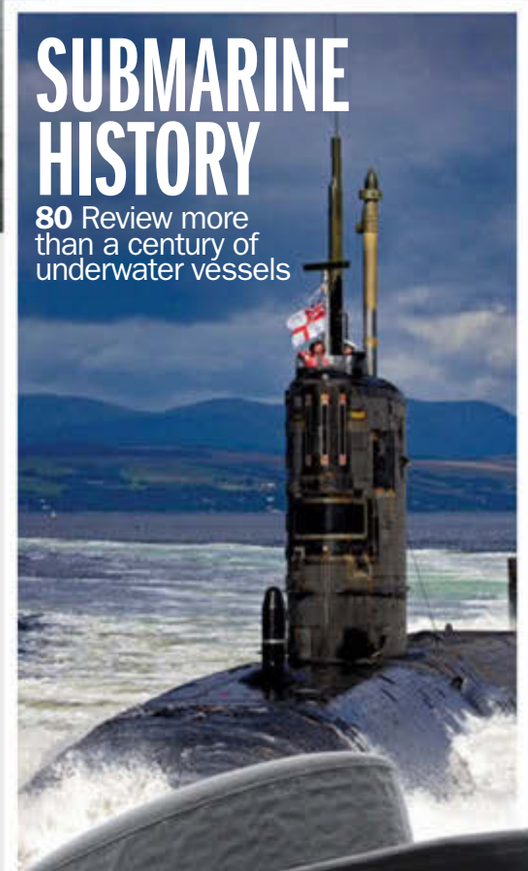
114 Discover the tech behind the vessels of the future

HMS MEDUSA

88 Decades on, the boat that led the D-Day assault has been restored

STEALTH SHIPS

SUPERCARRIERS



SUBMARINE HISTORY

HMS ALLIANCE

SUBMARINES

Some of the milestones in the history of these submerged military marvels

USS HOLLAND *1900*

Country: USA

Despite early prototypes being dismissed as not fit for purpose, the US Navy eventually bought John Holland's machine in 1900. It was the first to sport a fully functioning gasoline engine and an on-board generator that powered the submersible while below the surface.

The USS Holland was the first submarine to sport a gasoline engine

TURTLE *1776*

Country: USA

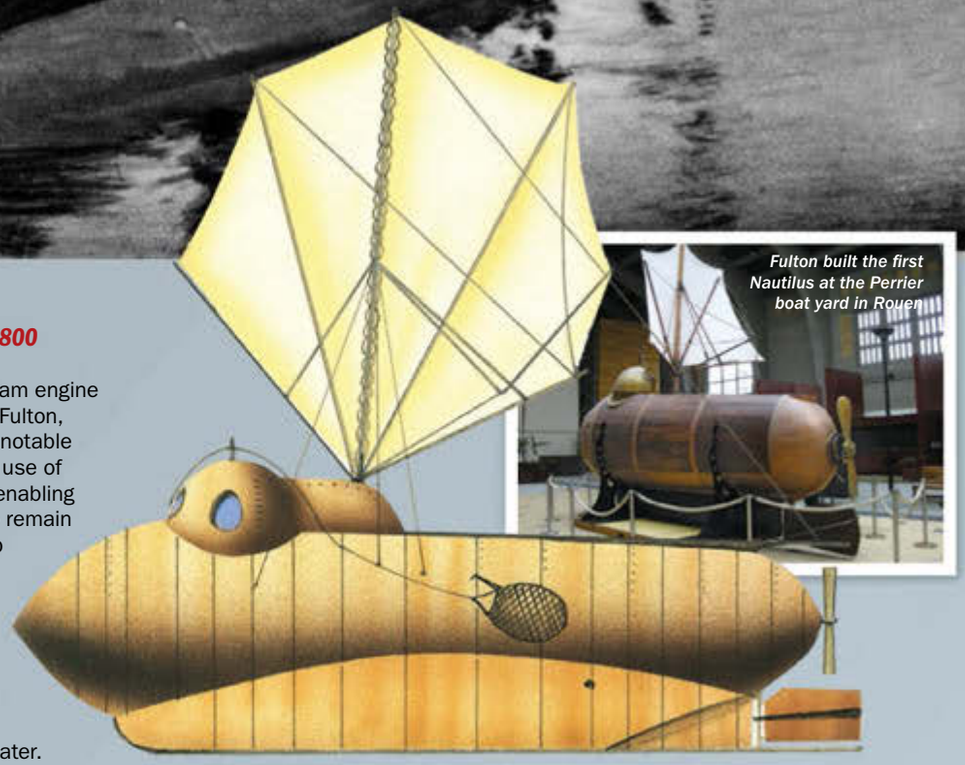
The Turtle was originally conceived by David Bushnell, a Connecticut-based inventor, before the start of the Revolutionary War (1775-1783). With air pipes to sustain the life of its driver, the Turtle also featured a hand-cranked oar that propelled the submersible and tanks that took on water to submerge the vehicle. These tanks would be emptied in order for the Turtle to re-surface.

David Bushnell's Turtle submarine was designed for single occupancy

NAUTILUS *1800*

Country: France

Developed by steam engine innovator Robert Fulton, the Nautilus was notable for its pioneering use of compressed air, enabling crew members to remain submerged for up to four hours. It also possessed a propulsion system and a sophisticated mechanism for manoeuvring vertically under water.



Fulton built the first Nautilus at the Perrier boat yard in Rouen

Six Trafalgar-class subs were in service with the Royal Navy

TRAFALGAR-CLASS *1981*

Country: United Kingdom

The line of sturdy Trafalgar-class British subs has been present in the Royal Navy's fleet since the early 1980s. Initially used as attack subs equipped with torpedoes and Tomahawk cruise missiles with a range of 1,000 miles, these machines now tend to be used to carry out reconnaissance and covert surveillance.

YANKEE-CLASS BMS *1968*

Country: Soviet Union

This fearsome ballistic missile submarine (BMS) was also equipped with sea mines and torpedoes. It occupied various oceans around the world from the 1960s onwards, operating en masse during the Cold War. It was the first Soviet submarine class to possess thermonuclear capabilities, representing a true threat to the West.

Yankee is just a nickname for the BMS class of Soviet sub

5 Facts about SUBMARINES

LAND OF THE FREE

Despite the tech being ahead of its time, both the Union and the Confederate States built and utilised primitive forms of submarines during the American Civil War of the 1860s.

AROUND THE WORLD

In 1960 the USS Triton became the first submersible in history to circumnavigate the Earth while submerged.

FOREVER BLOWING BUBBLES

The UK's new Astute-class subs have an on-board diffuser that emits carbon dioxide. This limits the amount of air bubbles that appear on the surface, to aid in concealment of the vessels.

PEACE TIME

The Royal Navy hasn't fired an underwater torpedo in live conflict since the sinking of the General Belgrano by HMS Conqueror during the Falklands War.

INTO THE ABYSS

The first submarine to reach the Challenger Deep – the deepest part of the ocean located in the Pacific (also known as the Marianas Trench) – was the bathyscaphe Trieste in 1960.

VIRGINIA-CLASS *1999*

Country: USA

Probably the most-advanced submarine model operating today, Virginia-class boats are capable of hunting and destroying enemy submersibles and frigates, attacking ground targets with cruise missiles and performing underwater recon. At a length of 377 feet, the Virginia class is capable of achieving in excess of 25 knots.

Commissioned in 2004, it's estimated Virginia-class subs will last until 2070

TYPE-VII U-BOAT *1935*

Country: Germany

The most infamous submarine ever built, the German U-Boat saw a significant amount of action during the Second World War and was responsible for the damaging or sinking of scores of Allied vessels. It played a key role in the Battle of the Atlantic, attempting to scupper Allied efforts to supply Britain with resources.

U-995 is the only surviving Type-VII class in the world

Getty

SUBMARINES OF THE WORLD

Discover the globe's best-known subs and their infamous encounters

1 RECON AT MIDWAY

PACIFIC OCEAN 4 JUNE 1942

US submarines prove to be key in ascertaining the strength and location of the Japanese fleet converging on Midway. In the ensuing battle, the US claims a decisive Pacific victory and the Imperial fleet is damaged beyond repair.

Alligator

Produced: **1862**
Speciality: **Protecting wooden ships from Confederate ironclads**
Location: **Philadelphia, USA**

HL Hunley

Produced: **1863**
Speciality: **Hunting Union warships**
Location: **Alabama, CSA**

2 UNDER THE POLE

THE NORTH POLE 3 AUGUST 1958

USS Nautilus, the world's first nuclear-powered submarine, makes history by reaching the North Pole and crossing it submerged, having set off from the United States some two months prior.

USS Nautilus enters New York Harbor in January 1956

Vetehinen-class

Produced: **1930**
Speciality: **Coastal mine-laying**
Location: **Finland**

Whiskey-class

Produced: **1949**
Speciality: **Coastal patrol**
Location: **Russia**

Kalev-class

Produced: **1935**
Speciality: **Laying mines**
Location: **Estonia**

Rota-ßclass

Produced: **1918**
Speciality: **Torpedo warfare**
Location: **Denmark**

Daphné-class

Produced: **1958**
Speciality: **Patrol and achieving greater depths**
Location: **Cherbourg, France**

Katsonis-class

Produced: **1925**
Speciality: **Offensive manoeuvres**
Location: **Greece**

Type-209

Produced: **1971**
Speciality: **Widely used deterrent**
Location: **Turkey**

Soviet K-class

Produced: **1936**
Speciality: **Long-range search and destroy**
Location: **Leningrad, Soviet Union**

Tikuna

Produced: **1996**
Speciality: **Attack submarine**
Location: **Brazil**

Scorpéne-class

Produced: **1999**
Speciality: **Offensive operations**
Location: **Chile**

3 THE FALKLANDS WAR

FALKLAND ISLANDS 30 APRIL 1982

The United Kingdom imposes a Total Exclusion Zone that surrounds the Falkland Islands, encompassing an area of 200 nautical miles. Any ships to enter this zone are fair game for British submarines.

4 KURSK DISASTER

NEAR MURMANSK, RUSSIA
12 AUGUST 2000
Oscar-class Russian sub Kursk is destroyed following a number of on-board torpedo explosions. The entirety of the boat's crew is killed, either by the initial explosions or from asphyxiation as fires break out in the aftermath.

The Kursk disaster claimed the lives of 118 Russian sailors, the full crew including five officers and two engineers

HMS Vanguard returns to HM Naval Base Clyde following CASD patrol in 2010

5 NUCLEAR TEST

FASLANE, SCOTLAND
26 MAY 1994
HMS Vanguard initiates the first test launch of a British nuclear Trident missile. Vanguard went on to embark on the first patrol that year in what is now the UK's ongoing strategy of continuous at-sea deterrence (CASD).

6 ATLANTIC BATTLE

JUST SOUTH-EAST OF BEAUFORT INLET, NORTH CAROLINA, USA
9 MAY 1942
German submarine U-352 is bested by patrol boat USCGC Icarus, under the command of the US Coast Guard. She is destroyed with depth charges, and her crew is taken prisoner by the US Navy.

Ghadir-class
Produced: **2006**
Speciality: **Recon and direct attack**
Location: **Tehran, Iran**

Type AM
Produced: **1943**
Speciality: **Command boats carrying sea-planes**
Location: **Japan**

7 UNDERWATER COLLISION

BAY OF BISCAY
4 FEBRUARY 2009
HMS Vanguard and French submarine Le Triomphant collide with each other in the Bay of Biscay, in what is a rather embarrassing incident for both the British and French Ministries of Defence. Both are nuclear subs, yet fortunately only sustain light damage.

8 LUSITANIA SUNK

SOUTHERN COAST OF IRELAND
7 MAY 1915
German U-boat U-20 fires a torpedo at HMS Lusitania, a passenger liner bound for Britain from New York. She sinks in only 18 minutes. A total of 1,195 passengers and crew are thought to have drowned.

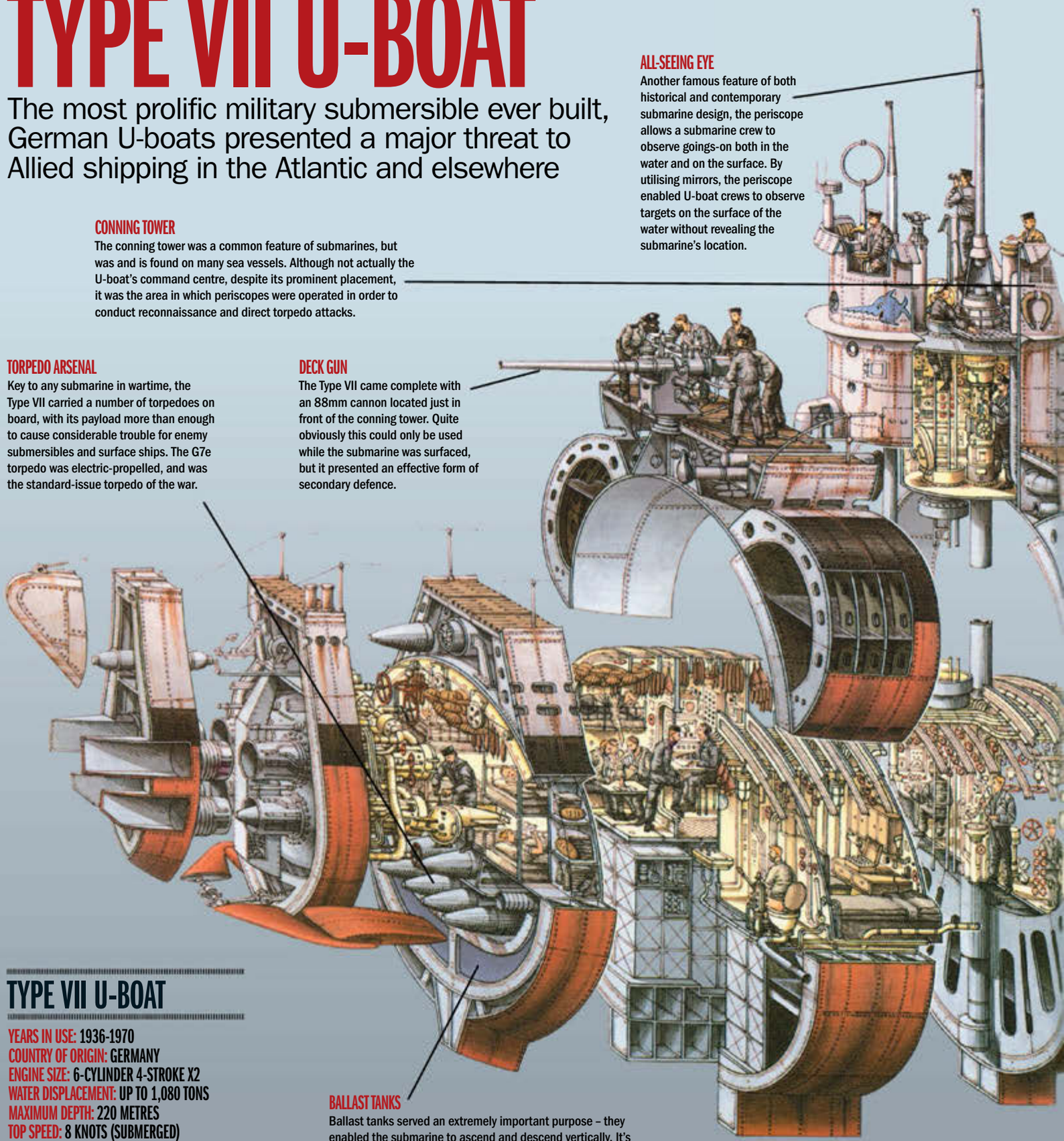
RMS Lusitania was briefly the biggest ship of her day

Corbis

Collins-class
Produced: **1990**
Speciality: **Attack sub**
Location: **Australia**

ANATOMY OF A...
TYPE VII U-BOAT

The most prolific military submersible ever built, German U-boats presented a major threat to Allied shipping in the Atlantic and elsewhere



ALL-SEEING EYE
Another famous feature of both historical and contemporary submarine design, the periscope allows a submarine crew to observe goings-on both in the water and on the surface. By utilising mirrors, the periscope enabled U-boat crews to observe targets on the surface of the water without revealing the submarine's location.

CONNING TOWER
The conning tower was a common feature of submarines, but was and is found on many sea vessels. Although not actually the U-boat's command centre, despite its prominent placement, it was the area in which periscopes were operated in order to conduct reconnaissance and direct torpedo attacks.

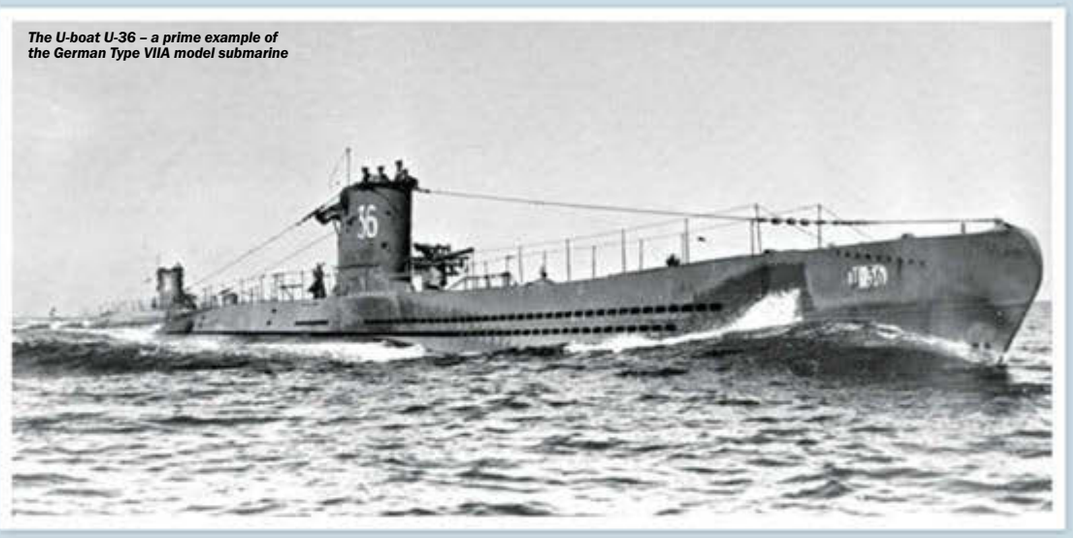
TORPEDO ARSENAL
Key to any submarine in wartime, the Type VII carried a number of torpedoes on board, with its payload more than enough to cause considerable trouble for enemy submersibles and surface ships. The G7e torpedo was electric-propelled, and was the standard-issue torpedo of the war.

DECK GUN
The Type VII came complete with an 88mm cannon located just in front of the conning tower. Quite obviously this could only be used while the submarine was surfaced, but it presented an effective form of secondary defence.

TYPE VII U-BOAT

YEARS IN USE: 1936-1970
COUNTRY OF ORIGIN: GERMANY
ENGINE SIZE: 6-CYLINDER 4-STROKE X2
WATER DISPLACEMENT: UP TO 1,080 TONS
MAXIMUM DEPTH: 220 METRES
TOP SPEED: 8 KNOTS (SUBMERGED)
WEAPONS: TORPEDOES, MINES AND DECK GUNS
CREW: UP TO 60, INCLUDING 4 OFFICERS

BALLAST TANKS
Ballast tanks served an extremely important purpose – they enabled the submarine to ascend and descend vertically. It's simple science, and an elegant solution – tanks inside the hull of the U-boat took on water to reduce buoyancy and enable the vessel to sink down out of sight.



The U-boat U-36 – a prime example of the German Type VIIA model submarine

ANTI-AIRCRAFT GUNS

If a Type VII were ever forced to return to the surface, it had some countermeasures on hand for any Allied aircraft that fancied taking a pop. This model would have been fitted with a 20mm flak cannon with a high rate of fire – more than enough to take down an Allied bird.

CREW QUARTERS

Life on a submarine was and still is difficult to adjust to. The crew quarters on a German U-boat were much like those found on other submarines of the Second World War – modest but functional. There were bunks, a lavatory and a small mess.

ENGINE ROOM

The meat and bones of the vessel, the Type VII U-boat's engine room housed its two six-cylinder, four-stroke diesel engines. Also on board were electric engines powered by two large batteries that enabled the boat to move while it was submerged. The diesel engines acted as dynamos, recharging the electric motors while the submarine was surfaced.

PROPELLERS AND RUDDER

On the surface, these Type VIIs operated in much the same way as any other vessel. As expected, the propellers were key for driving the submersible forwards at a reasonable rate, while the rudder enabled left and right turns – this was very important when it came to navigating around mines and other dangerous obstacles.

SINGLE HULL

Like most antiquated submarine designs, the Type VII U-boat employed a single hull, but it was also reinforced with sturdy rib-like bands of steel to further fortify its outer shell. This was mostly to protect the craft against water pressure at significant depths.

DK Images

HEAD TO HEAD

If the Cold War had ever heated up, there was plenty of firepower on offer. Here are two opposing nuclear submarines that served in these years of military tension

K-43

SOVIET NAVY, RUSSIAN NAVY

MISSILES

The K-43 was the first Soviet submarine with submerged launch SS-N-7 anti-ship missiles (eight of them, in fact) so it didn't have to make risky surfaces.

TORPEDOES

Either 12 SS-N-15 anti-submarine missiles or 12 torpedoes were fitted to the K-43, giving it a formidable underwater arsenal.

SPEED

Using its single five-blade propeller, the K-43 could reach a speed of 16 knots when surfaced and 23 knots when underwater.

POWER TYPE

A first-generation VM-5 nuclear reactor was used to propel the ship and powered the impressive 20,000shp steam turbine.

TECHNOLOGY

This advanced submarine contained the all-new Snoop Tray surface-search radar, which helped seek out targets for missile strikes.

TOTAL

THE PROJECT 670 CHARLIE CLASS

The K-43 was one of 17 submarines in the USSR's nuclear-powered Project 670 Charlie class. The class was split into two, with the K-43 forming the first group of subs. The first batches of Soviet submarines were diesel-electric powered and based on captured German models but, Charlie was part of the new nuclear unit launched in 1967. The class's main role in the Soviet Navy was surprise attacks on aircraft carriers. The model survived the fall of the Soviet Union and was retired in 1994. It was succeeded by the Papa class of submarine, which boasted a titanium hull and a higher top speed.

The K-43 operated in the Soviet Navy until 1988 when it was sold to the Indian Navy

"THE CLASS'S MAIN ROLE IN THE SOVIET NAVY WAS SURPRISE ATTACKS ON AIRCRAFT CARRIERS"

THE JAMES MADISON CLASS

The James Madison class of US submarine was part of the '41 for Freedom' group of 41 submarines that provided nuclear protection for the USA. The class was named after the country's fourth president and replaced the Lafayette class. They originally carried Polaris A-3 missiles but were later modified to carry Trident weapons. To accommodate the advanced missiles, the submarines were fitted with the best guidance and navigation systems money could buy. Ten were made in total and they served the US Navy for over 30 years and were succeeded by the Benjamin Franklin and Ohio classes.

Trident missiles were first introduced in 1979 and are still used by both the US and UK

This submarine was named after Kazimierz Pułaski (1745–1779), a Polish General who fought for the US in the American War of Independence

USS CASIMIR PULASKI

US NAVY

MISSILES

The submarine was armed with either 16 Polaris or Poseidon ballistic missiles that made use of the first ever satellite navigation system, TRANSIT.

TORPEDOES

Four MK-45 nuclear torpedoes were held onboard. An airlock was used to adjust the projectile to the change in atmospheric pressure when launched into the sea.

SPEED

The Casimir Pulaski could easily race to speeds of over 20 knots, giving it a slight pace advantage over its Soviet rivals from the era.

POWER TYPE

Two steam turbines were turned by a S5W nuclear core, a new type of propulsion system that replaced the S1W in 1971.

TECHNOLOGY

Noise-dampening technology was used to make the submarine as undetectable as possible and the vessel contained a Trident missile targeting system.

TOTAL

"TO ACCOMMODATE THE ADVANCED MISSILES, THE SUBMARINES WERE FITTED WITH THE BEST GUIDANCE AND NAVIGATION SYSTEMS MONEY COULD BUY"

HMS MEDUSA

In June 1944, HMS Medusa served as the lead navigation ship on D-Day, guiding allied crafts through enemy minefields

During the course of WWII, over 480 Harbour Defence Motor Launches (HDMLs) were built to defend the United Kingdom's coasts against the German submarine threat. In the early years of the war there was a real fear U-boats could encircle the country and cut off its vital ports and harbours, so these small vessels were intended to build a screen of defence, identifying and sinking any enemy boats. When this threat didn't materialise, the HDMLs were put to work in a whole range of other tasks, such as defending convoys, inserting agents into enemy territory and supporting attacks on islands.

The vessels truly came into their own during Operation Neptune, when they guided allied craft through the deadly enemy minefields of the English Channel on D-Day. In the lead up to the assault, minesweepers carved two channels towards Omaha beach, where American troops would soon be facing some of the toughest resistance of the landings. Vessels ML 1383 and 1387 were positioned as beacons to these channels and would remain for over 30 hours, guiding the allied craft packed with men and equipment on their way to the beaches of Normandy.

Designed to be small, silent, agile and incredibly flexible, HDMLs weren't intended for longevity. Of the original 480 or so craft, only one remains operational today: ML 1387, now called the HMS Medusa. Built in Poole, UK, in 1943, the Medusa took part in Exercise Fabius in May 1944, which was a practise operation for D-Day, before providing crucial support of the landings themselves.

The HMS Medusa, commission in 1943 and built in Poole, UK, served allied ships during the war, guiding them through enemy waters

***Left:** The crew of HMS Medusa, HDML 1397, including Commanding Officer TSLt Arthur Maurice Liddiard RNVR*

***Below:** At its current moorings in Gosport, UK*

ML 1387 'HMS MEDUSA'

COMMISSIONED: 29 DECEMBER 1943
CREW: 12
LENGTH: 72 FEET
ORIGIN: DORSET, UK
TOP SPEED: 12 KNOTS
ENGINE: TWIN DIESEL GARDNER 8L3S
WEIGHT: 54 TONS (WATER DISPLACEMENT)

"HDMLS WERE PUT TO WORK DEFENDING CONVOYS, INSERTING AGENTS INTO ENEMY TERRITORY AND SUPPORTING ATTACKS"

The Chart Room aboard the HMS Medusa, this was where Sub Lt Maurice Liddiard would have outlined the ships involvement in D-Day

OERLIKON 20MM AUTOMATIC CANNON

Each of the two deck-mounted cannons were manned by one gunner strapped in by a harness. This helped the gunner to easily manoeuvre the weapon almost 360 degrees, as well as upward to a nearly fully vertical angle. A safety feature was built into the mechanism of the mount to prevent the weapon rotating a full 360 degrees, as gunners were prone to accidentally damaging their own vessel as they turned and followed their target. The guns carried 60-round magazines, and were capable of delivering 480 rounds per minute. This meant even a brief squeeze of the trigger for just over seconds could expel an entire magazine into the enemy. Bursts of fire like this were ideal against diving Stuka bombers and other aircraft.

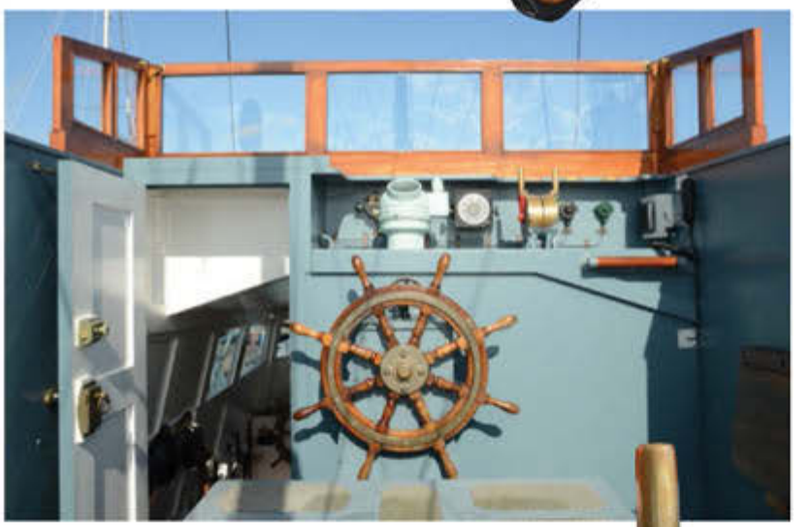
The manoeuvrability of the 20mm gun made it perfect for levelling fire at both aircraft and targets on the surface

Two nearby lockers each contained four extra magazines for reloading the gun

Medusa currently has only one 20mm gun, put together from donations and chance findings at scrap yards

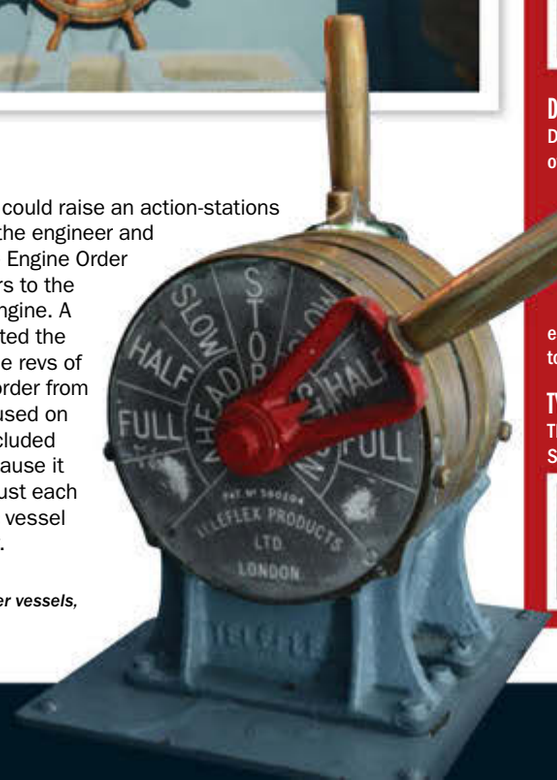
TWIN VICKERS 'K' MACHINE GUNS

Two twin Vickers machine guns could be mounted on the vessel, one each on the port and starboard sides. These gas-operated guns were each capable of between 900 and 1,200 rounds per minute and were originally developed for the RAF. They were ideal for dealing with enemy aircraft, as well as providing supporting fire.



THE BRIDGE

From here the commanding officer could raise an action-stations alarm, as well as communicate to the engineer and the radio operator below deck. The Engine Order Telegraph (EOT) would deliver orders to the engineer, with one lever for each engine. A bell ringing in the engine room alerted the engineer, who would then adjust the revs of each engine to correspond to the order from the EOT at his end. Just like EOTs used on much larger vessels, the orders included Full Ahead, Stop and Slow, but because it took a small amount of time to adjust each engine, slowing or accelerating the vessel would not have happened instantly.



The EOT system was typical of much larger vessels, but was included on HDMLs as standard

ELECTRONIC WARFARE AT D-DAY

MEDUSA WAS EQUIPPED WITH SOME OF THE MOST CUTTING-EDGE TECHNOLOGY, ALL MANNED BELOW DECK BY A LONE OPERATOR

GEE NAVIGATION SYSTEM

Designed for the RAF to improve the accuracy of its bombers, this system was accurate to within a quarter of a mile. Three stations on the shore would send out simultaneous pulses, each of which would be received by the Gee, then the timings between each pulse would determine the location of the vessel. Because it was feared that the Germans would be able to block the signal of the Gee, new transmitters and receiver modules were developed just for D-Day

DECCA SYSTEM (QM)

Developed in Canada and tested at the Firth of Forth, where it was less-likely to be picked up by the Germans, this system was kept highly secret prior to D-Day to prevent it being jammed. The system was integral to the planning of Operation Neptune, even to the point that ship positions, movements and routes were planned with the Decca signal in mind. Only 20 of these units were used on the most-essential vessels during D-Day and Medusa was only one of two HDMLs to be fitted with one.

TYPE 291 RADAR

This standard-issue radar was adapted from a system used on Sunderland flying boats. Much less-sophisticated than modern-day PPI (Plan Position Indicator) displays, the Type 291 could simply how far away a target was. It was capable of identifying a destroyer at around six miles away. An IFF system (Indicate Friend Foe) would also indicate where allied or unidentified objects in the area.

THE ENGINE ROOM

HDMLs were fitted with two diesel engines and one generator to charge the electricity. There would be an engineer manning the engine room at all times, on alternating shifts of 12 hours. Cruising at around 600 revs per minute, the vessel would consume an average of seven gallons of fuel per hour between all three engines. With room to store 1,550 gallons of fuel on board, the vessel could stay at sea for over 2,000 nautical miles. It was the job of the engineer to ensure that fuel was consumed equally between tanks on both the port and starboard sides of the boat, so that the craft remained level and balanced, rather than lopsided.

Below: *In the event a depth charge was dropped to attack a submarine, the engineer could boost each engine's revs to 900 per minute so the vessel could escape the blast!*

Above: *The two engines could produce less than 300 horsepower between them – they were built for endurance, not power*

Below: *Engines were regularly swapped out of older and into newer craft by the Admiralty and weren't originally designed to last more than five years*

SUBMARINE DETECTION

The original purpose of HDMLs was to seek out and destroy submarines. A large metal dome on the underside of the vessel would send out sonar pings, which would then return back any objects within range. The size and direction of a submarine would be displayed on the automatic graph, and the crew would easily be able to manoeuvre the vessel to pursue it.

This box (left) contained a detonator that was to be used by the commanding officer to destroy all the classified equipment on the vessel, if it were at risk of being captured by the enemy

THE WARDROOM

The skipper and first officer occupied this room near the aft of the vessel. Though it was nearly the exact size of the galley area, which housed six of the crew, the two officers occupied this space in relative comfort, complete with an alcohol cabinet, furnishings and the vessel's safe. This safe contained the crew's pay, the captain's orders, side arms, a flare gun and any other sensitive documents. A bell system connected to the galley was also in place, for the officers to call for their meals or other attention from the crew. It was here that refugees hide when they were aboard the vessel.

THE MEDUSA TRUST

WWW.HMSMEDUSA.ORG.UK

Set up in 2003, the Medusa Trust worked tirelessly to raise funds for the refit of the vessel, which was in need of drastic restoration work. "In order to do the sort of fundraising we needed to do, she needed to be part of a charitable trust," says Medusa's current skipper and Chairman of the Trust Alan Watson. "The whole purpose of the Trust was to restore, operate and maintain this vessel, but it has broadened slightly. As well as this vessel we're also guardians of the history of all the HDMLs… We are the last crew of the last HDML now, which is a bit special." Along with coxswain and historian of the Medusa, Brian Holmes, the Trust continues to piece together the history of these vessels and the stories of their crew for future generations.

HMS ALLIANCE

Take a tour of the mechanics, weapons and operating systems of Britain's last surviving Second World War submarine

A veteran submarine hunter from the Cold War, HMS Alliance is a diesel-electric submarine and the tenth constructed from the Amphion class of the Royal Navy. The 16 in its class were ordered to be constructed in 1943 when Imperial Japan was becoming a danger to the Allies in the Pacific theatre of war. However, by V-J Day none of the submarines had been commissioned in time to see war and were instead thrust into the Cold War.

Alliance was designed for long-distance patrolling at a range of around 16,100 kilometres (10,000 miles) with up to 30 days underwater. The submarine used a technique learnt from the Germans called 'snorkelling' or 'snorting', which allowed the vessel to travel long distances with a steady supply of fresh air. Alliance went under a huge overhaul in 1958 to get it up to speed with the tough seas of the Cold War. With the new additions it became a key part of the Royal Navy despite running aground in 1968 and a fire in 1971 that killed one and injured 14.

The submarine slipped into retirement in 1973 as the Oberon and Porpoise class of submarine took over. It was then used as training boat until 1981 when it became a memorial to the 4,334 submariners who lost their lives in both World Wars and the 739 who have been killed in peacetime disasters. It is now the centrepiece of the Royal Navy Submarine Museum in Gosport, Hampshire.

Left *HMS Alliance clocked up thousands of miles as it monitored submarines from the Red Fleet during the Cold War*

HMS ALLIANCE

TYPE: A-CLASS FIGHTING VESSEL
COMMISSIONED: 14 MAY 1947
ORIGIN: UK
LENGTH: 85M (281FT)
ENGINE: TWIN DIESEL-ELECTRIC
CREW: 68 (FIVE OFFICERS, 63 RATINGS)
TOP SPEED: 18.5 KNOTS (SURFACED) 8 KNOTS (SUBMERGED)
PRIMARY WEAPON: 12 MARK VIII TORPEX TORPEDOES
SECONDARY WEAPONS: 4IN GUN, 20MM AA GUN, 3 .303 MACHINE GUNS, 26 MINES

"ALLIANCE WAS DESIGNED FOR LONG-DISTANCE PATROLLING AT A RANGE OF AROUND 16,100 KILOMETRES (10,000 MILES) WITH UP TO 30 DAYS UNDERWATER"

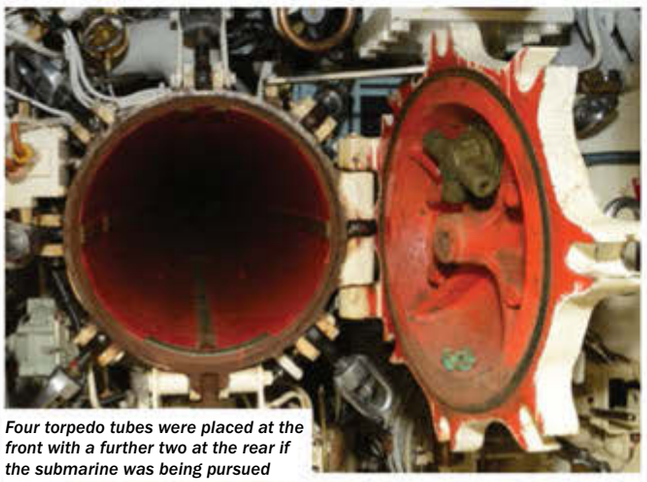
Left: *With its all-welded hull, Alliance made submarines stronger and quicker off the production line*

Below: *Alliance as it looks today. The museum was given £7 million in 2013 to stop it rusting away*

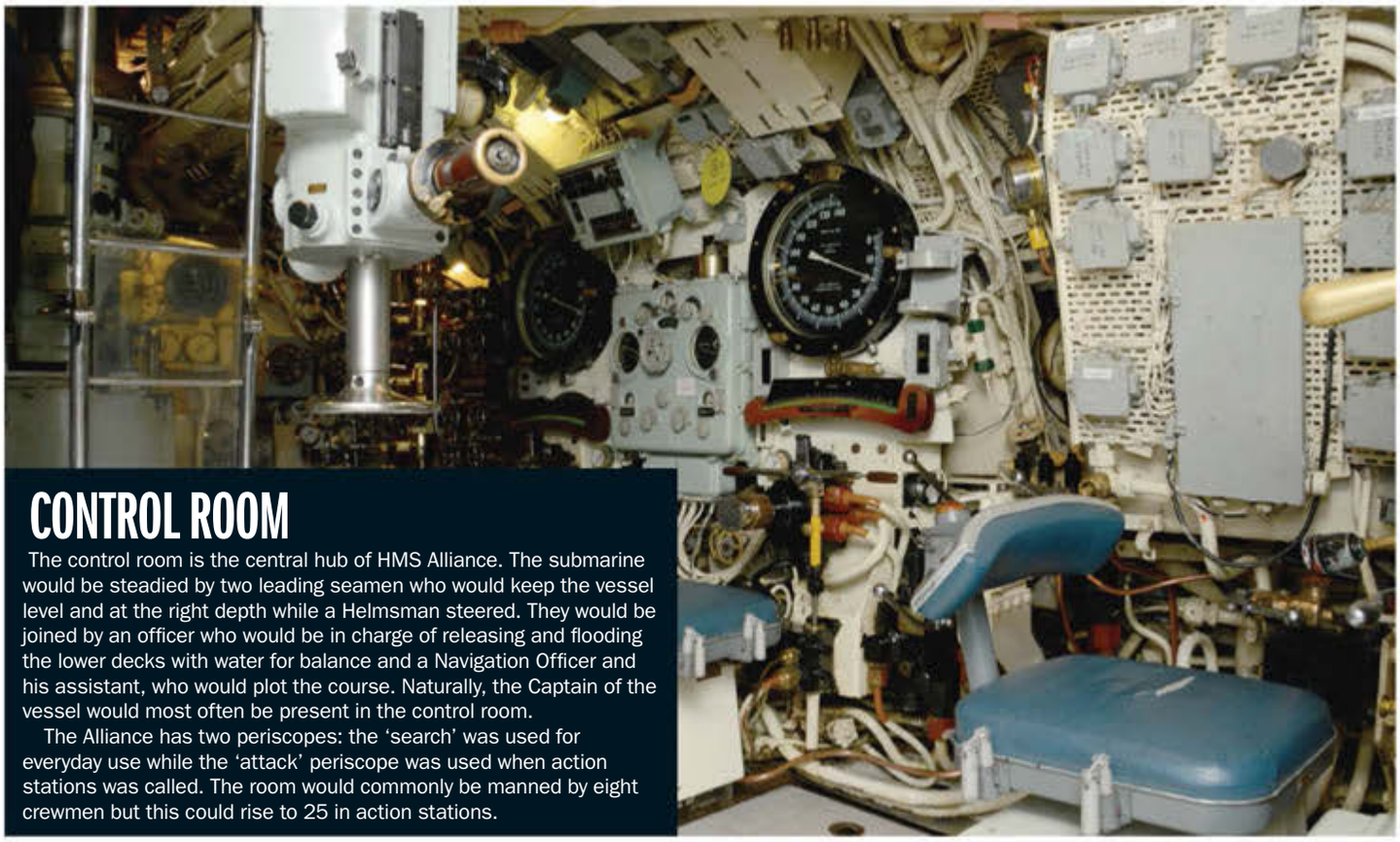
TORPEDOES

The weapon systems of Alliance were vital, despite the fact that the Cold War never reached open hostilities. The vessel could carry up to 12 torpedoes at a time, which would be fired in a triple salvo at enemy submarines and ships.

The weapons of choice for the Alliance were two-ton Mark VIII torpedoes with a 730lb explosive torpex head. These would be fired just below the surface at the side of a ship for maximum damage. The Mark VIII would later be phased out by the Tigerfish Torpedo, which boasted a magnetic proximity fuse that would explode when in the locality of the target.



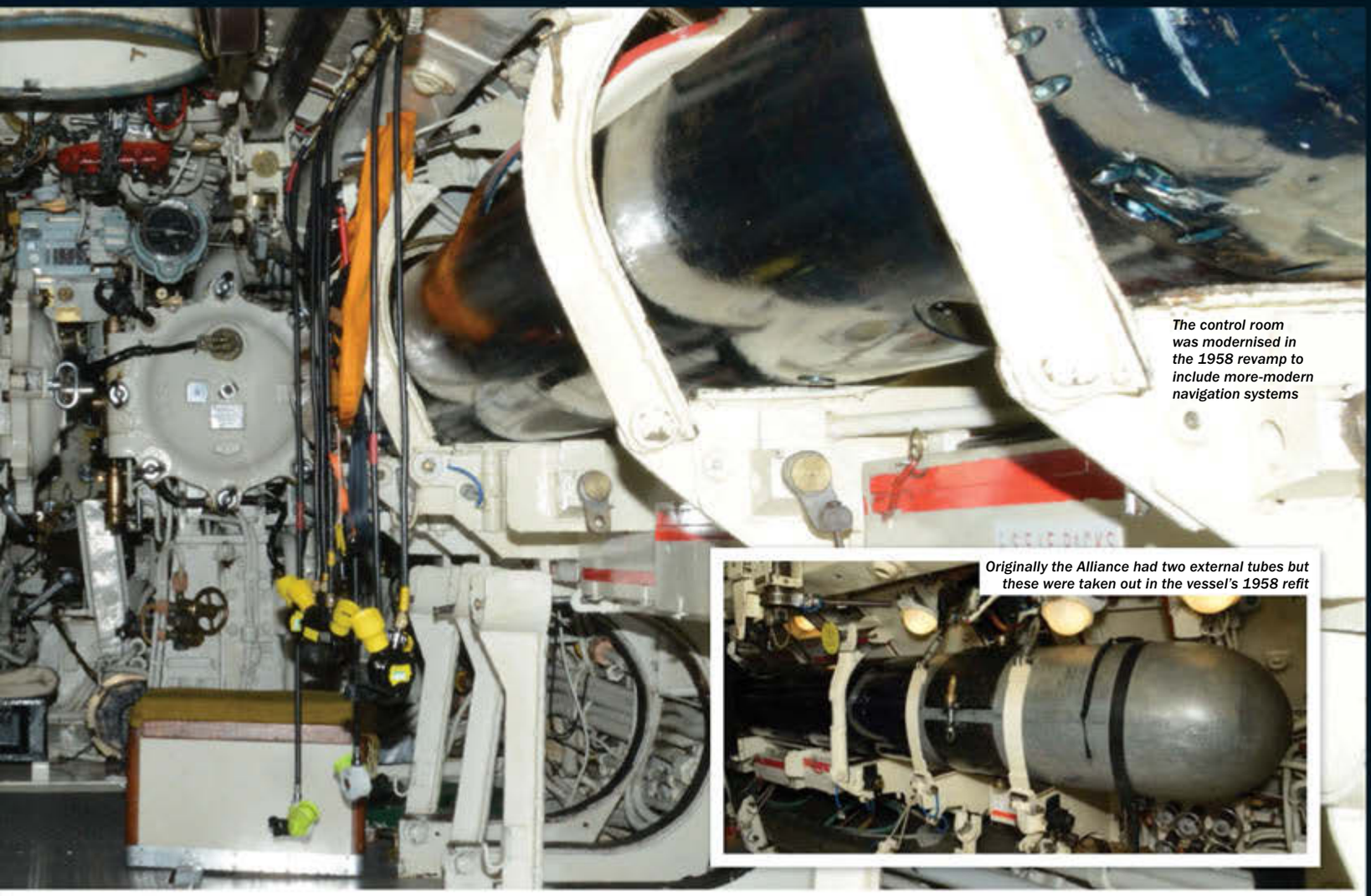
Four torpedo tubes were placed at the front with a further two at the rear if the submarine was being pursued



CONTROL ROOM

The control room is the central hub of HMS Alliance. The submarine would be steadied by two leading seamen who would keep the vessel level and at the right depth while a Helmsman steered. They would be joined by an officer who would be in charge of releasing and flooding the lower decks with water for balance and a Navigation Officer and his assistant, who would plot the course. Naturally, the Captain of the vessel would most often be present in the control room.

The Alliance has two periscopes: the 'search' was used for everyday use while the 'attack' periscope was used when action stations was called. The room would commonly be manned by eight crewmen but this could rise to 25 in action stations.



The control room was modernised in the 1958 revamp to include more-modern navigation systems

Originally the Alliance had two external tubes but these were taken out in the vessel's 1958 refit

"THE WEAPONS OF CHOICE FOR THE ALLIANCE WERE TWO-TON MARK VIII TORPEDOES WITH A 730LB EXPLOSIVE"

PROPELLERS

Thanks to its diesel-electric system, the HMS Alliance was capable of 18.5 knots on the surface and eight knots when submerged. Sluggish when compared with the ships of the era, this was equal to the majority of submarines at least until the nuclear era led by the launch of USS Nautilus.

Although imposing, the propellers were remarkably quiet and the Alliance was an extremely discreet ship, which helped it to no end when tracking Soviet subs across the oceans. The boat's direction was controlled from the stern by fore planes, which adjusted depth, and after planes that controlled the angle of the submarine.

THE OTHER AMPHION-CLASS SUBS

WHAT HAPPENED TO ALLIANCE'S SISTER SUBMARINES?

HMS ALDERNEY (P416)

Like the Alliance, Alderney went under an expensive refit in 1958 to get it up to scratch. The submarine was part of various Royal Navy submarine squadrons and was primarily used in training exercises with the Royal Canadian Navy and Air Force. It was decommissioned in 1966 and eventually scrapped in 1970.

HMS AFFRAY

The last Royal Navy submarine lost at sea, the HMS Affray was involved in a training exercise that went horribly wrong in April 1951. The Submarine sunk during the operation in the English Channel after supposed system defects or possible battery explosion. All 75 of the crew perished in the disaster.

HMS ARTFUL

The Artful was put 'on loan' to the Royal Canadian Navy as a training submarine in 1951 but returned to the reserve and the 5th Submarine Squadron in 1954. From then on it participated in Home Fleet Squadron Tours until its scrapping in 1972.

ENGINE ROOM

The engine room was by far and away the nosiest, hottest and dirtiest place on the submarine. The twin diesel-electric engines dominated the room, which was hot and humid at nearly all times. Seasickness was common in this room and the pointed stern of the submarine made the area move in a figure of eight when advancing through the sea.

The lives of the engineers on board weren't safe either – as space is lacking on a submarine, open valves and electrical circuits were everywhere. Some of these open blades could have up to 440 volts of direct current running through them. With the advent of nuclear subs, the safety aspects of their engine rooms were forced into a priority, for obvious reasons.

The engine room shook so much, many submariners strapped buckets to themselves for when seasickness struck!

THE 1958 REFIT

The HMS Alliance was built for the war in the Pacific and Far-East operations, so when the Second World War ended and the Cold War escalated, some of its features became obsolete. The 20mm anti-aircraft gun was deemed surplus to requirement, as rival submarines became the enemy rather than ships and aircraft. The 1958 refit concentrated on making the Alliance much more streamlined so it was even quieter than it had been and therefore more difficult for sonar to detect. As nuclear submarines began to take over, HMS Alliance didn't find itself becoming obsolete, instead it occupied a much more niche role of obtaining information and undertaking reconnaissance missions.

The original vessel had a 20mm anti-aircraft gun, but it was phased out after the refit as technology advanced

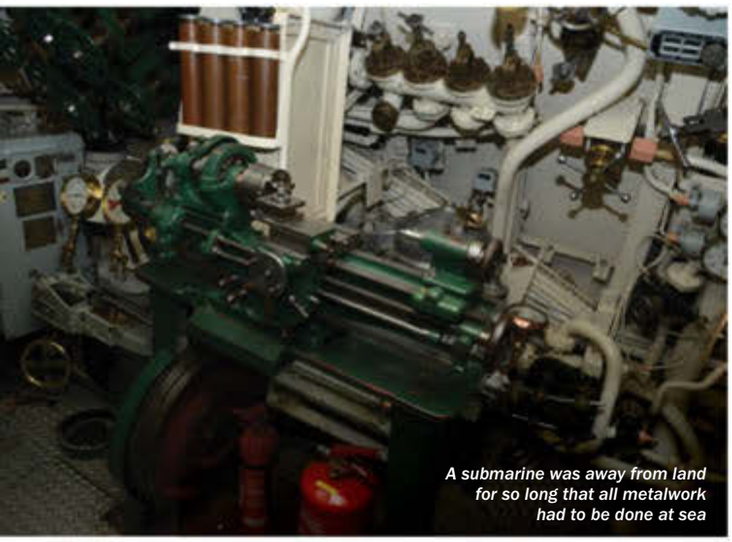
Left: *The conning tower was replaced after the 1958 refit as the Alliance's role changed to a sub-hunter*

"THE TWIN DIESEL-ELECTRIC ENGINES DOMINATED THE ROOM, WHICH WAS HOT AND HUMID AT NEARLY ALL TIMES"

As part of the recent restoration project, the stern has been reconstructed following corrosion damage

ROYAL NAVY SUBMARINE MUSEUM

The Royal Navy Submarine Museum has been at its current location in Gosport, Hampshire, and open to the public since 1978. HMS Alliance was donated to the museum in the same year as its principal exhibit. The museum attracts 50,000 visitors a year and doubles up as a memorial to all British submariners who have given their lives in service. Its continuing mission is to 'tell the story of the Royal Navy Submarine Service'. **Visit www.submarine-museum.co.uk for opening hours and admission information.**



A submarine was away from land for so long that all metalwork had to be done at sea

The Duke of Cambridge came aboard on 12 May 2014 to observe the inner workings of Britain's last surviving Second World War submarine

LIFE ABOARD A SUBMARINE

JJ MOLLOY SERVED AS A WEAPONS ENGINEER ON HMS WALRUS, HMS OPPORTUNE AND HMS SEALION DURING THE COLD WAR.

WHY DID YOU CHOOSE TO JOIN THE NAVY AND BECOME A SUBMARINER?

I joined the navy thinking I would go onto aircraft carriers and have a good life sunning myself in warm climates. I finished my training but I was drafted onto submarines instead.

WHAT'S IT LIKE TO BE OUT AT SEA AND UNDER THE WAVES ON OFTEN LONG OPERATIONS?

It's a very peaceful existence. The submarines are designed to be quiet and the crew is quiet. You get up do your job and go back to bed. It's all about routine. You don't really notice the space after a while because you're so used to it. Everyone knows where they've got to be and what they've got to do, so you don't bump into people. Claustrophobia has never been a problem.

WHAT WERE YOUR DAY-TO-DAY DUTIES LIKE ON BOARD THE SUBMARINE?

Although I was a weapons engineer, the duties I had also included the ship's control, so I was in fact a Helmsman as well. I also went on regular tube space watch and ensured the weapons system was consistently maintained.

WHAT OPERATIONS WERE YOU INVOLVED IN?

Submarines in the Cold War era were constantly on the look out for Soviet submarines, and in fact any other submarines. If we came across them we would record their sound and follow them as far as the rules of engagement would allow. We'd also practice in case the Cold War went hot by surveying ship's movements and gathering intelligence.

TELL US ABOUT THE HMS ALLIANCE'S 1958 REFIT

Alliance was built for Far East operations during World War Two. She missed the end of the war, so by the time she was operational, it was the Cold War where other submarines became the enemy. Therefore, the Royal Navy submarines were streamlined in order to become quieter and more difficult to detect.

HOW DID DIESEL-ELECTRIC SUBMARINES COPE IN THE NUCLEAR AGE?

They were for a different purpose. Diesel-electric submarines are much quieter when they've dived compared with nuclear subs and are harder to detect. Diesel-electric submarines made excellent listening platforms but they were much, much slower.

Rex Features

WHERE DO ALL THE ROYAL NAVY SUBMARINES COME FROM?

INSIDE THE LARGEST INDOOR SHIPBUILDING COMPLEX IN EUROPE

The HMS Alliance is one of many submarines to have been born in the dock of Barrow-in-Furness. A town and seaport in Cumbria, it has provided submarines to the Royal Navy for over a century. The port originally produced all types of naval ships but it has been solely submarines since the 1960's. Construction and investment had since declined but there has been a rebirth of sorts in recent years. Now owned by defence and security firm, BAE Systems, the Devonshire Dock Hall complex is receiving a £300 million refurbishment in an eight-year cash injection. The current class of submarine is known as Vanguard but the upgrade, known simply as the 'Successor Programme' will usher in a new wave of developments intended to replace the Trident System. The addition of these plans to the new Queen Elizabeth class of aircraft carriers demonstrates how far the Royal Navy has come since the days of HMS Alliance.

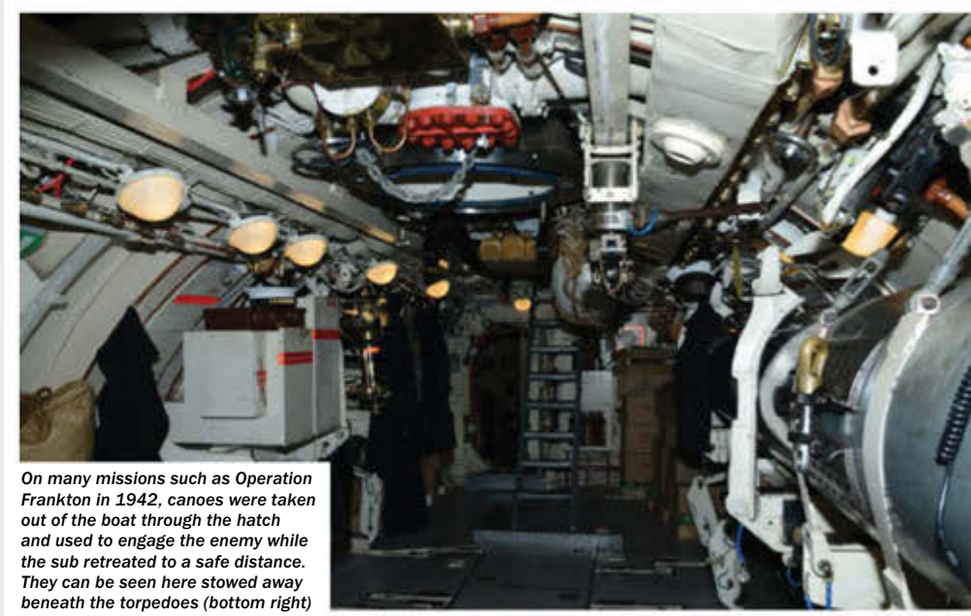
Above: *The shipyard at Barrow-in-Furness as it is currently (left) and how it could look after the investment (right)*

FROM AMPHION TO UPHOLDER

THE RISE AND DEMISE OF DIESEL-ELECTRIC SUBMARINES IN THE ROYAL NAVY

When Britain's first nuclear powered submarine HMS Dreadnought was completed on the 17 April 1963, many assumed that it would mark the end of diesel-electric submarines like HMS Alliance. This was not to be however, and the Porpoise, Oberon and Upholder classes all followed the Alliance and its Amphion class. The Upholders in particular were a vast improvement . First commissioned in 1990, they were intended to be a new generation of submarine in post-Falklands Britain. The new fleet utilised two 16-cyclinder engines that had an immensely high power to weight ratio. Its weapons also packed a punch with upgraded wire-guided heavyweight torpedoes, anti-ship missiles and submarine mines. However, despite the modern technology, a cut in Royal Navy finances meant the four vessels were put up for sale within two years of their completion. A buyer was eventually found in 1998 as the whole class was purchased by the Royal Canadian Navy. They are still in service in Canada to this day as the UK focuses its efforts fully on nuclear submarines.

HMCS Windsor, part of the Upholder class purchased by Canada in 1998



On many missions such as Operation Frankton in 1942, canoes were taken out of the boat through the hatch and used to engage the enemy while the sub retreated to a safe distance. They can be seen here stowed away beneath the torpedoes (bottom right)

The larder had to be stocked full for long journeys submerged under the waves

"THE PORPOISE, OBERON AND UPHOLDER CLASSES ALL FOLLOWED THE ALLIANCE AND ITS AMPHION CLASS, BRINGING VAST IMPROVEMENTS"

HMS ALLIANCE TIMELINE: THE UNUSUAL LIFESPAN OF A UNIQUE VESSEL

1945
Built to serve in the Far East against Imperial Japan, HMS Alliance is laid down in March and launched in July.

1947
After test cruises the submarine is completed and commissioned in May. However, by the time it is ready to see action, the war has already ended.

1958
In order to bring her up to speed with contemporary standards, Alliance is given an extended refit and overhaul, streamlining and modernising the entire vessel.

1968
Runs aground on the Bembridge Ridge on the Isle of Wight in January but is repaired in time to participate in the N.A.T.O. Exercise in the Mediterranean on 5 November.

1971
On the 30 September there is a battery-related explosion on board the Alliance that kills one member of the crew and injures 14 others.

1973
Taken out of active service in March to become a static display ship at HMS Dolphin, Gosport. It is now solely used for harbour training duties.

1979
The decision is taken by the Royal Navy to prepare the Alliance for permanent display. Her keel is strengthened so she can be lifted on to land.

1981
Preserved as a submarine memorial and museum ship at the Royal Navy Submarine Museum. It is an enduring monument to the 4,334 submariners who lost their lives on active duty for Britain in both world wars.

F/A-18C/D HORNET

UNIT COST $29 MILLION
MAX SPEED MACH 1.7+
PROPULSION 2X F404-GE-402 TURBOFAN ENGINES (17,700LB STATIC THRUST EACH)
CEILING 50,000+FT
COMBAT RANGE 1,089NM (1,253MI, 2,000KM)

E-2 HAWKEYE

UNIT COST $80 MILLION
MAX SPEED 300KTS+ (345MPH, 552KM/H)
PROPULSION 2X ALLISON T-56-A427 TURBOPROP ENGINES
CEILING 30,000FT (9,100M)
CREW 5

AIRCRAFT CARRIERS

Living on an aircraft carrier can be a stimulating, equally exhausting experience. Learn why, despite its name, there can be no room for passengers…

Aircraft carriers of the world don't come much larger than the US Navy's nuclear-powered Nimitz-class. At 4.5 acres and stretching 1,092 feet, the flight deck of USS Abraham Lincoln dwarfs the Chrysler Building. Despite its awesome profile, however, its role is more than symbolic. The carrier can balance and mobilise a seagoing airbase of multiple strike and combat support aircraft, with a ship's company of over 5,000 souls. It can deploy anywhere within international waters while retaining the sovereign territory of its home place of berth. Therefore, unlike an airbase stationed on foreign soil, no permission for landing or complex overflight rights are required.

Despite its loner appearance, however, the aircraft carrier is not without friends; it is often flanked by a more nimble carrier 'battle' group that can offer added protection, tactical options and extra supplies to the fleet.

NUCLEAR-POWERED NIMITZ

America's Nimitz-class aircraft carriers are powered by two small on-board pressurised water reactors (PWR), which drive the ship's four steam turbines that not only power four five-bladed propellers, but also generate enough electricity to power everything on the ship. The nuclear reactions taking place in the PWRs can generate enough power to reach a top speed of 30 knots. Inside the reactor cores a huge amount of energy is given off due to fission – the splitting of large atoms (uranium) into smaller ones and releasing kinetic energy in the process.

There are two separate loops inside each aircraft carrier's nuclear power station. The primary loop contains superheated water, or coolant (in liquid form). This coolant is pumped through the uranium-fuelled reactor – where it reaches temperatures of up to 900°F – under high pressure so it doesn't boil inside the core. This superhot water is then passed through a steam generator. The heated water in the primary loop doesn't get converted to steam itself (because it's under high pressure), rather the intense heat of it is used to convert the cooler water in the separate secondary loop into turbine-driving steam to power the generator. And because the loops are separate and the water never mixes, the radioactivity is safely contained in the reactor of the primary loop. The steam from the turbine is then cooled and condensed, converting it back into liquid water ready to run the cycle again.

The reactors rarely require refuelling – maybe once every 25 years – offering carriers practically unlimited range. Refuelling involves removing the used core and replacing it with a shiny new one replenished with enriched uranium nuclear fuel.

EA-6B PROWLER

UNIT COST $52 MILLION
MAX SPEED 500KTS+ (575MPH, 920KM/H)
PROPULSION 2X PRATT & WHITNEY J52-P408 ENGINES (10,400LB THRUST EACH)
CEILING 37,600FT
COMBAT RANGE 1,000+NMI (1,150MI, 1,840KM)

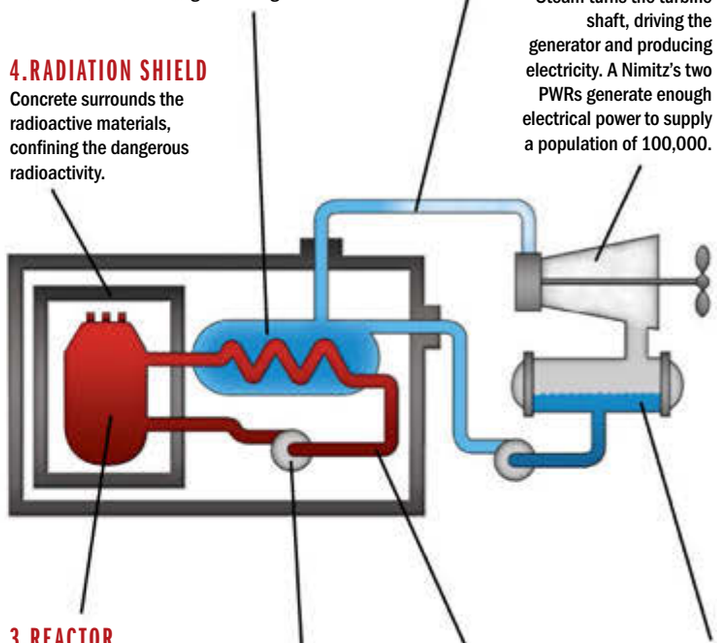
SH-60 AND MH-60 SEAHAWK HELICOPTER

UNIT COST $5.9 MILLION TO $10.2 MILLION
MAX SPEED 180KTS (207MPH, 333KM/H)
PROPULSION 2X T700-GE-700 OR T700-GE-701C ENGINES
CREW 3-4
RANGE 380NMI (437MI, 600KM) AIR REFUELLING MAKES RANGE ULTIMATELY UNLIMITED

F/A-18E/F SUPER HORNET

UNIT COST $57 MILLION
MAX SPEED MACH 1.8+
PROPULSION 2X F414-GE-400 TURBOFAN ENGINES (22,000LB STATIC THRUST EACH)
CEILING 50,000+FT
COMBAT RANGE 1,275NMI (1,467MI, 2,346KM)

"WHEN WORD OF CRISIS BREAKS OUT IN WASHINGTON, IT'S NO ACCIDENT THE FIRST QUESTION THAT COMES TO EVERYONE'S LIPS IS 'WHERE IS THE NEAREST CARRIER?'"



5.STEAM GENERATOR
The steam generator uses heat from the coolant in the primary loop to turn the water in the secondary loop to steam ready to turn the turbine. Once the coolant's heat is released at the steam generator, the colder coolant returns to the reactor to go round again.

6.STEAM
The steam created in the secondary loop turns the turbine, driving a generator that produces electricity.

8.TURBINE
Steam turns the turbine shaft, driving the generator and producing electricity. A Nimitz's two PWRs generate enough electrical power to supply a population of 100,000.

4.RADIATION SHIELD
Concrete surrounds the radioactive materials, confining the dangerous radioactivity.

3.REACTOR
Nuclear fission of uranium fuel takes place inside the tightly sealed reactor, releasing huge amounts of heat (between 500°F and 900°F), which is transferred to the coolant.

1.PRIMARY COOLANT PUMP
Circulates coolant around the reactor and through the steam generator.

2.PRESSURISED WATER (COOLANT)
Natural water is superheated but doesn't boil because it is kept under high pressure.

7.CONDENSER
This device turns the steam into liquid by cooling it. The condensed water is then piped back into the steam generator to be reheated again.

THE AIRCRAFT ON BOARD

There are around 85 aircraft on board a Nimitz-class, including dozens of different types capable of taking out enemy aircraft and ground targets, performing electronics warfare to mess with enemy radars, providing early warning signals for tactical operations, and attacking submarine enemies.

Although the flight deck is big, all 85 aircraft cannot be parked up top so most are stowed in the carrier's hangar bay. Over 60 aircraft can be kept two decks down in a three-deck high area that extends more than two thirds of the length of the carrier.

INSIDE THE HANGAR'S HIDDEN DEPTHS

Hangars serve as dual-purpose maintenance and storage facilities for half the carrier's aircraft contingent at any one time, with the remainder in flight or housed on the flight deck.

Typically each bay is separated by a steel dividing door; a throwback to Kamikaze raids of WWII to confine and limit the incendiary threat of fire. The hangar and flight deck are connected by lifts. With its increased capacity, the Nimitz-class carriers like the USS Abraham Lincoln operate four deck edge high-speed elevators, each capable of lifting two F/A-18 jets; in so doing it can relocate eight aircraft simultaneously from hangar to flight deck in a matter of seconds.

The USS Abraham Lincoln, see the cutaway below for more detail

HITTING THE DECK

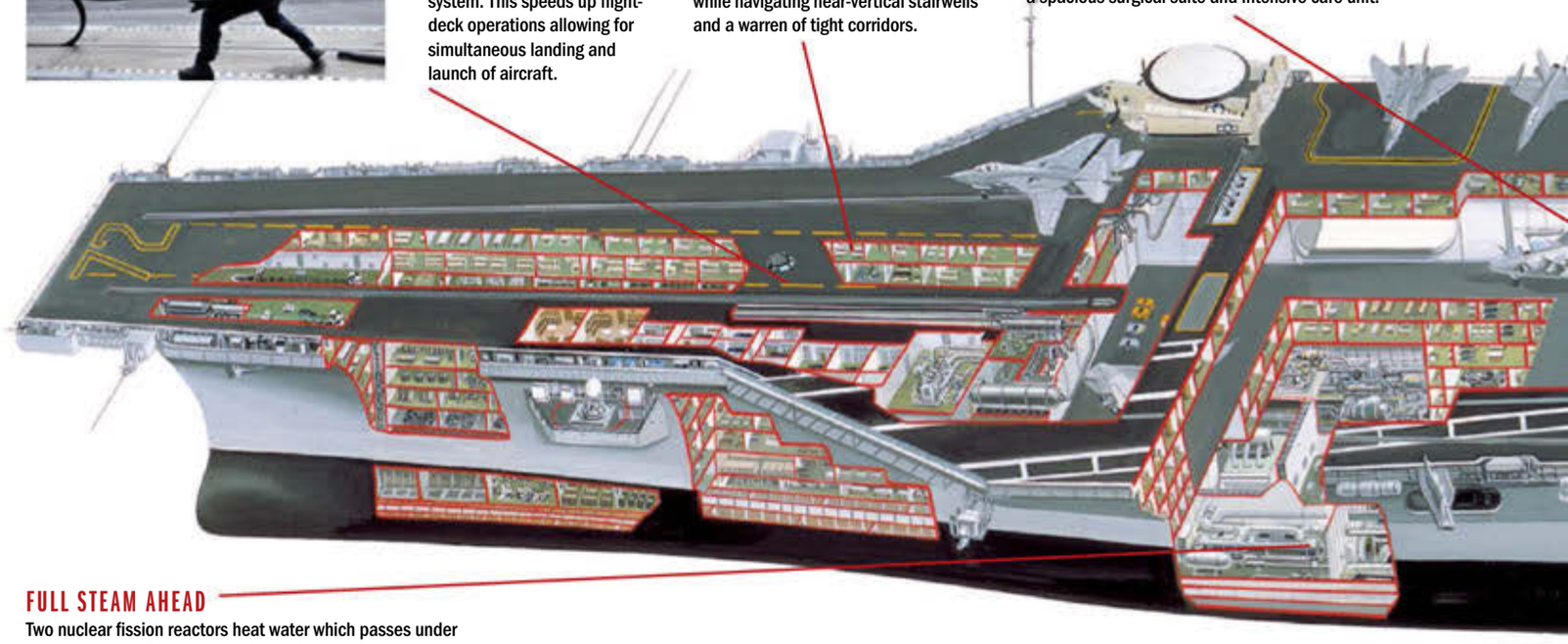
Two angled flight-decks support the CATOBAR (Catapult Assisted Take Off But Arrested Recovery) system. This speeds up flight-deck operations allowing for simultaneous landing and launch of aircraft.

CUTTING CREW QUARTERS

Crew typically endure cramped living quarters with triple-stacked bunks, often sharing compartments and toilet facilities with upwards of 60 people while navigating near-vertical stairwells and a warren of tight corridors.

IS THERE A DOCTOR ON BOARD?

Yes. The medical department is located under the hangar deck to ease patient access, offer stability during surgical procedures and protection from damage under fire. On Nimitz-class carriers it operates a spacious surgical suite and intensive care unit.



FULL STEAM AHEAD

Two nuclear fission reactors heat water which passes under pressure driving four steam turbines that turn four bronze propellers – each measuring 20ft and weighing 30 tons apiece – to achieve a maximum speed of 35 knots (equivalent to 40mph). The protruding bulbous bow adds buoyancy, reducing drag for enhanced handling and propulsion. It adds extra lift to the flight deck that aids in an aircraft's launch.

"THE NIMITZ-CLASS MUST CARRY ENOUGH SUPPLIES TO SATISFY A THREE-MONTH STRETCH AT SEA"

HOW DO YOU SUSTAIN A CREW FOR MONTHS?

While the 2,480-strong air wing busies itself with flying and maintaining the aircraft, the 3,200 ship's company crew provide the supporting carrier services ranging from nuclear reactor maintenance to culinary services and scrubbing the dishes.

The Nimitz-class must carry enough food and supplies to satisfy a three-month stretch at sea, with multiple kitchens and mess halls that satisfy the three-meal-a-day appetite of all those living and working on board. To wash this down each ship boasts desalination units, converting an ocean of seawater into 400,000 gallons of freshwater to be used by the crew.

During downtime the cramped crew compartments that house 60 or so men each offer small commons room access with a TV reception. Catching up with home is made easy with banks of phones via satellite link-up, a ship's newspaper, post office and its own postcode! Other necessities and opportunities for work and distraction include a hospital, dental practice, general stores, laundry facilities, library and a barbershop.

THE ISLAND

Approaching 50m tall the tower is one tenth as wide at the flight deck where space is at a premium. It bristles with radar and communication antenna that can sense the proximity of the fleet, target encroaching threats and receive TV/satellite reception.

THE CAPTAIN'S VIEW

The primary flight control (or 'Pri-Fly') is home to the Air Boss. With a crow's nest view of proceedings and an array of GPS receivers and radar screens to hand, he choreographs the well-oiled ritual of take-off and landings, flight-deck manoeuvres and those in-flight aircraft in close proximity to the ship.

Below, the Bridge is home to the Officer of the Deck (OOD) – appointed on four-hourly rotations by the Commanding Officer (Captain). He stays at his station while 'under sail' and is responsible for all safety and operational decisions from navigation through to communications. With its computer-enhanced air detection systems, the nearby CDC (Combat Direction Centre) provides the Tactical Action Officer with real-time data to assist his role in supporting the CO in both defensive and offensive operations.

THE CAPTAIN'S LOG

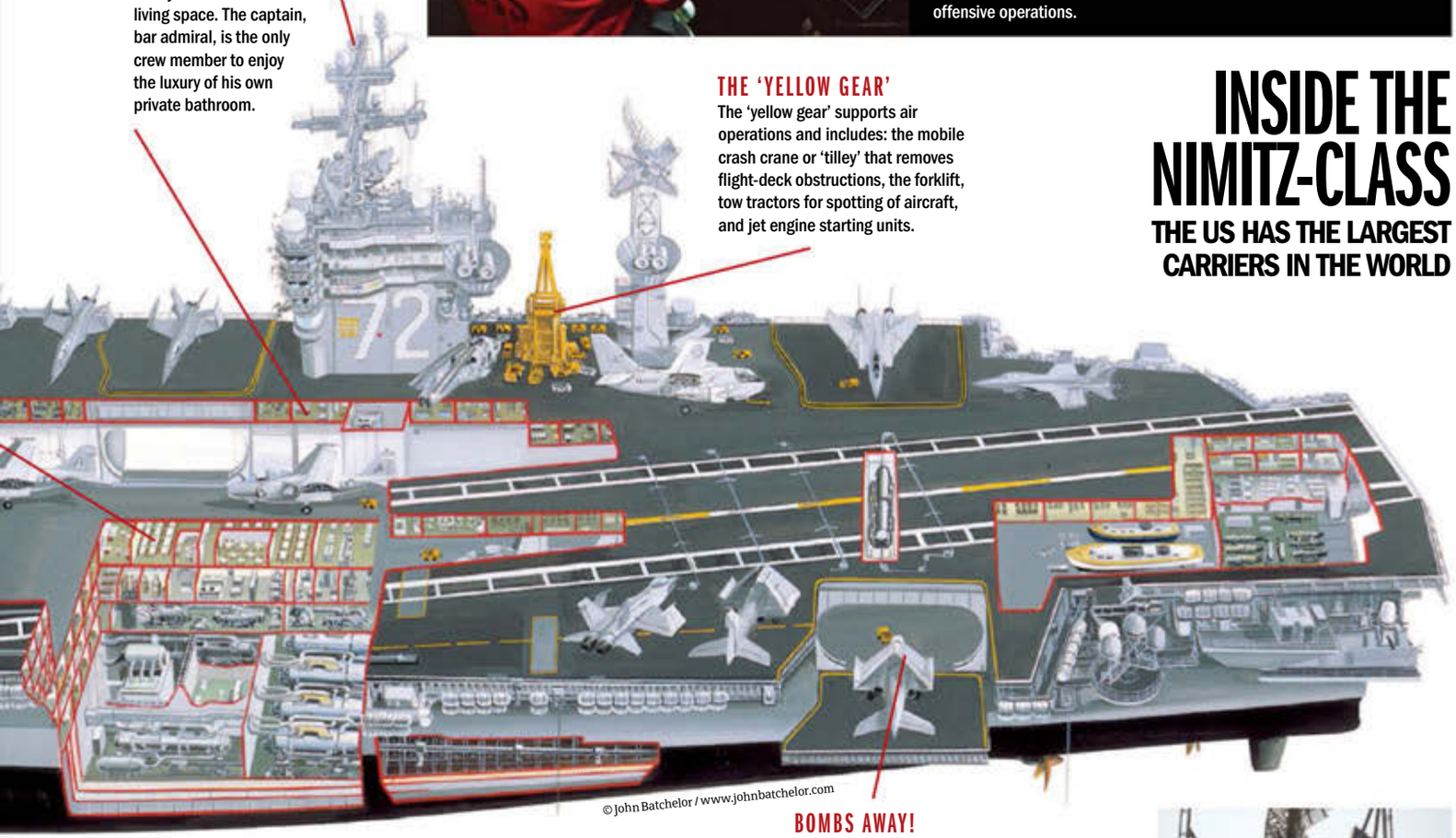
The captain's quarters double as office space and afford comparative luxury with a 30x30-foot living space. The captain, bar admiral, is the only crew member to enjoy the luxury of his own private bathroom.

THE 'YELLOW GEAR'

The 'yellow gear' supports air operations and includes: the mobile crash crane or 'tilley' that removes flight-deck obstructions, the forklift, tow tractors for spotting of aircraft, and jet engine starting units.

INSIDE THE NIMITZ-CLASS

THE US HAS THE LARGEST CARRIERS IN THE WORLD



A VESTED INTEREST

Coloured vests signify flight-deck function. The whites represent safety officer and crew; blue are the aircraft handling and chock crewmen; green is the catapult and arrest crews; yellow includes the catapult/flight-deck officers; and brown, the plane captains.

BOMBS AWAY!

Stored in magazines on the lower deck, weapons are transferred to below flight deck by bomb elevators; once assembled they are transferred to carts and the flight deck elevators where they can be manually fitted by flight deck crew.

LANDING ON A POSTAGE STAMP

Despite its 4.5 acres, the carrier has limited space and planes require mechanised support to take off and land. Aircraft are spotted by tractors, readied with fuel pumped from tanks below deck and primed with missiles. During a take off the carrier speeds into the wind, causing air to flow over the deck. This acts in conjunction with powerful steam-driven 'Fat Cat' catapults that propel 30-ton jets with the necessary speed and lift to launch at a rate of up to four every minute.

Hitting a 'postage stamp' on open water, aircraft rely on 1.375-inch-thick arrest cables, suspended five inches off the flight deck, separated at 35-40 foot intervals. These cables connect to hydraulic cylinders that act as giant shock absorbers. When the tail hook connects with a cable it pulls a piston within a fluid-filled chamber of the cylinder; as it's drawn down energy is absorbed, bringing aircraft to a halt.

Smaller carriers forgo the CATOBAR system for short take-off and vertical landing (STOVL). The RN developed a 'ski jump' ramp to help launch aircraft that require little or no forward movement to take off or land.

TYPE 45 DESTROYER

The British Navy's new Type 45 destroyer, HMS Diamond, is an insane piece of next-generation hardware capable of dominating future battlefields

5 Facts about TYPE 45 DESTROYER

BORDER
The Type 45 has over 20,000 power and data cables on board. Laid end-to-end they'd stretch from Glasgow in Scotland to the Ministry of Defence offices near Bristol, England.

ANGEL
The Type 45 is 44 metres from keel to the pinnacle of its radar dome. That is twice the height of architect Antony Gormley's Angel of the North sculpture in Gateshead, England.

ICONIC
The flight deck of the Type 45 is large enough to park 20 double-decker buses on it at any one time. In reality, the flight deck will mostly be used to carry Merlin-class helicopters.

BIG APPLE
The Type 45 has a range of 7,000 nautical miles, which is a distance equivalent to travelling from Britain to New York and back again without the need for refuelling.

CRICKET
The anti-missile system fitted to the Type 45 can deal with multiple targets at once, detecting, tracking and ultimately destroying any threat down to the size of a cricket ball.

HMS Diamond being constructed at the BAE Systems naval shipyard on the River Clyde

Arguably, the Type 45 Diamond destroyer is the most advanced air-defence warship in the world. Centred around the omniscient SAMPSON Multi Function Radar – a system that can track the movement of every moving object within a 400km circumference – and the Sea Viper anti-air missile system, which can launch eight high-explosive Aster missiles every ten seconds (each 20 times more manoeuvrable than the fastest Formula 1 car), the Diamond has set a new standard for destroyers worldwide.

Indeed, not only is it capable of delivering a biblical amount of firepower to a multitude of targets, but it is almost invisible to radar systems too, appearing like nothing larger than a fishing boat to enemy systems. This illusion works as the Diamond has been designed from the ground up so it sports zero right angles and actively cools all exhaust gases, dramatically reducing its signature while at sea. This, when partnered with the fact that the Type 45 destroyers have a range of 7,000 nautical miles, gives the Diamond the ability to operate extensive tours in battlefields across the globe, remaining all-but invisible throughout.

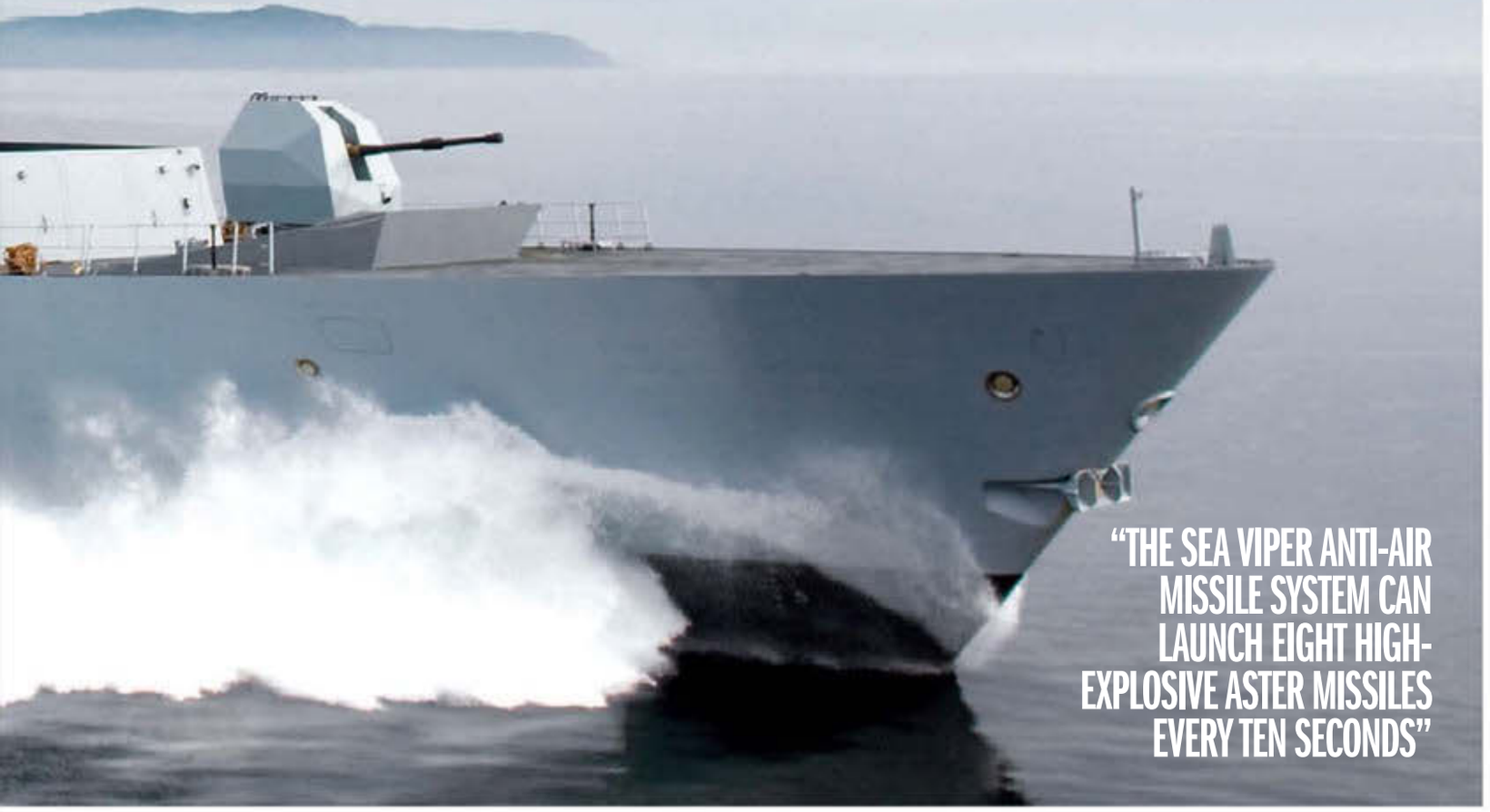
The impressive statistics continue throughout the Type 45, which notably is the first front-line warship class to use all-electric propulsion. This grants the Diamond destroyer the advantage of being 100 per cent run off a single power plant, be that its dual 47MW Rolls-Royce WR-21 turbines for propulsion, its Sea Viper Anti Air Missile System for fire power, or merely its iPod charging points in crew quarters for entertainment. Further, due to this all-electric running, the Diamond has no gearbox – a notorious source of mechanical problems for previous destroyers – as well as fewer installed prime movers and running prime movers, facts that maximise the amount of time the ship is operational and lower its total running costs.

HMS Dauntless and HMS Astute at sea

Interestingly, however, despite the fact that HMS Diamond and its fellow Type 45s feature state-of-the-art weaponry, stealth and detection systems, the materials that are used in its overall construction are of just a standard shipbuilding type, reducing the investment needed to bring a unit to completion. This cost efficiency is mirrored in its maintenance procedures too, with crucial components such as its engines easily accessible and removable through access plates.

Delivered to the British Royal Navy on 22 September, the HMS Diamond is the third Type 45 destroyer to be delivered out of a total of six planned units, with the HMS Dragon, HMS Defender and HMS Duncan to follow over the next three years.

HMS Diamond leaves the River Clyde shipyard



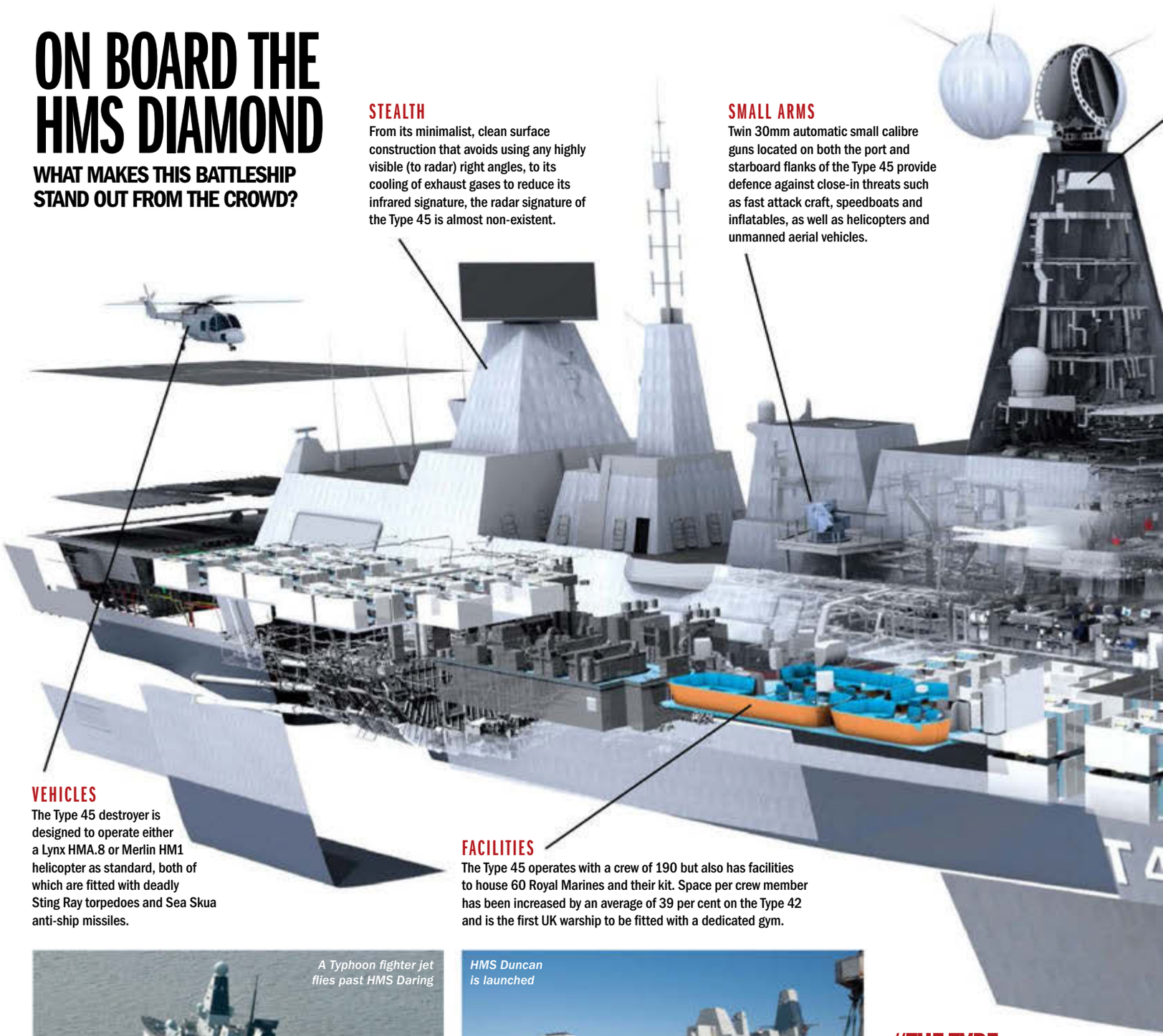
"THE SEA VIPER ANTI-AIR MISSILE SYSTEM CAN LAUNCH EIGHT HIGH-EXPLOSIVE ASTER MISSILES EVERY TEN SECONDS"

ON BOARD THE HMS DIAMOND

WHAT MAKES THIS BATTLESHIP STAND OUT FROM THE CROWD?

STEALTH
From its minimalist, clean surface construction that avoids using any highly visible (to radar) right angles, to its cooling of exhaust gases to reduce its infrared signature, the radar signature of the Type 45 is almost non-existent.

SMALL ARMS
Twin 30mm automatic small calibre guns located on both the port and starboard flanks of the Type 45 provide defence against close-in threats such as fast attack craft, speedboats and inflatables, as well as helicopters and unmanned aerial vehicles.



VEHICLES
The Type 45 destroyer is designed to operate either a Lynx HMA.8 or Merlin HM1 helicopter as standard, both of which are fitted with deadly Sting Ray torpedoes and Sea Skua anti-ship missiles.

FACILITIES
The Type 45 operates with a crew of 190 but also has facilities to house 60 Royal Marines and their kit. Space per crew member has been increased by an average of 39 per cent on the Type 42 and is the first UK warship to be fitted with a dedicated gym.

A Typhoon fighter jet flies past HMS Daring

HMS Duncan is launched

All pictures © BAE Systems

"THE TYPE 45 OPERATES WITH A CREW OF 190"

THE HISTORY OF DESTROYERS

TRACKING THE EVOLUTION OF THE DESTROYER WARSHIP OVER THE PAST 120 YEARS

1893
The first ships to be classed as destroyers were the Daring and Havock class. These Royal Navy destroyers were armed with a

12-pounder, three six-pounders and three 46 centimetre torpedo tubes.

1909
At the turn of the 20th Century destroyer technology evolved, and ships adopted steam turbines as the new method of

propulsion. They were more efficient and allowed for greater speeds.

1928
The development of fighter planes led destroyers to be tailored to deal with their attacks. The Japanese Fubuki class typifies

these developments, with high-angled gun turrets in addition to larger cannons.

RADAR

The Type 45's long-range multi-function radar has an epic range, capable of detecting hundreds of inward- and outward-moving targets for up to 400 kilometres. Its primary mission is to detect sea-skimming missiles, but it can literally track every moving target within its range with ease, delivering an incredibly comprehensive picture of the entire battlefield.

The multi-function radar

SEA VIPER

As a primarily anti-aircraft/missile battleship, the main offensive capability of the Type 45 comes from its Principle Anti-Air Missile System (PAAMS), a joint French/Italian/British anti-aircraft weapon know as the Sea Viper. Designed to both protect the Type 45 from all missile and aircraft threats, as well as provide air defence for ground forces when close to shore, the system is capable of launching eight Aster missiles every ten seconds.

The Diamond Type 45 destroyer in dock

MEDIUM CANNON

The BAE systems 4.5in Mk8 Mod 1 naval gun grants the Type 45 both fire support and shore bombardment capabilities, as well as an additional option in anti-surface warfare operations. The cannon receives commands from an electro-optical gunfire control system.

HMS DIAMOND

CREW 190
LENGTH 152.4M
BEAM 21.2M
DRAUGHT 7.4M
POWER TWO ROLLS-ROYCE WR-21 GAS TURBINES (21.5MW EACH), TWO WARTSILA V12 VASA32 DIESEL GENERATORS (2MW EACH), TWO CONVERTEAM ELECTRIC MOTORS (20MW EACH)
MAX SPEED 29 KNOTS
MAX RANGE 7,000 NAUTICAL MILES
ARMAMENT ONE PAAMS AIR DEFENCE SYSTEM WITH 48 ANTI-AIR ASTER MISSILES, ONE BAE SYSTEMS 4.5-INCH MK 8 MOD. 1 GUN, TWO 30MM GUNS, TWO MINIGUNS, SIX GENERAL-PURPOSE MACHINE GUNS
VEHICLE COMPLEMENT LYNX HMA8, WESTLAND MERLIN HM1

MATERIALS

Despite the Type 45 being one of the most advanced warships in the world, it has been designed so that it can be built from standard shipbuilding materials. This ensures that military investment is focused on the destroyer's defensive and offensive systems.

1943

During the Second World War, submarines and next-generation fighter planes posed a new threat to destroyers that led to radical new weapons systems and sonar to be installed.

1972

The Iroquois class of destroyer was built especially for anti-submarine warfare, which became more prevalent. They were fitted with anti-jet aircraft-guided missiles when refitted in the Nineties.

2010

The Type 45 is the world's most advanced destroyer, honed to remain nearly invisible to radar and sonar while packing a huge number of anti-aircraft missiles. Its radar can track targets up to 400 kilometres away.

STEALTH WARSHIPS

We lift the lid on the latest covert vessels that are taking the art of sneaking to a whole new level

Stealth relies on five core principles when it comes to military vessels: materials, coatings, geometry, noise and tactics. While the latter is situation dependent, the first four are physical qualities that can be modified to enhance stealth with advanced technologies.

Materials are based on composites such as fibreglass rather than hard metals and the incorporation of negative-index metamaterials (NIMs). These latter artificial substances are designed to be all-but invisible to specific radar frequencies. Some vessels are also being built with demagnetisation belts – a process that involves encircling a ship with superconducting ceramic cables.

Covering a vessel with radar-absorbent coatings such as iron ball paint – tiny spheres of carbonyl iron or ferrite – can also reduce a radar cross-section. Coatings are referred to as RAMs (radar-absorbent materials) and work by transforming radar waves into heat energy. This process works as the carbonyl iron coating has an alternating magnetic field, which when hit by radar waves begins to oscillate at a molecular level, trapping the incoming signal within the material and dissipating its energy as heat.

Geometry is also crucial to remaining undetected. In terms of radar, complex structures offer a far crisper, easier-to-identify return image than those with a simple geometry. As such, modern stealth warships and submersibles are designed with this in mind, often installing protective domes over the mast and sensors, called radomes. Similarly, today's vessels have incredibly clean and angled hulls with few doors and faceted hangars, to minimise their radar footprint.

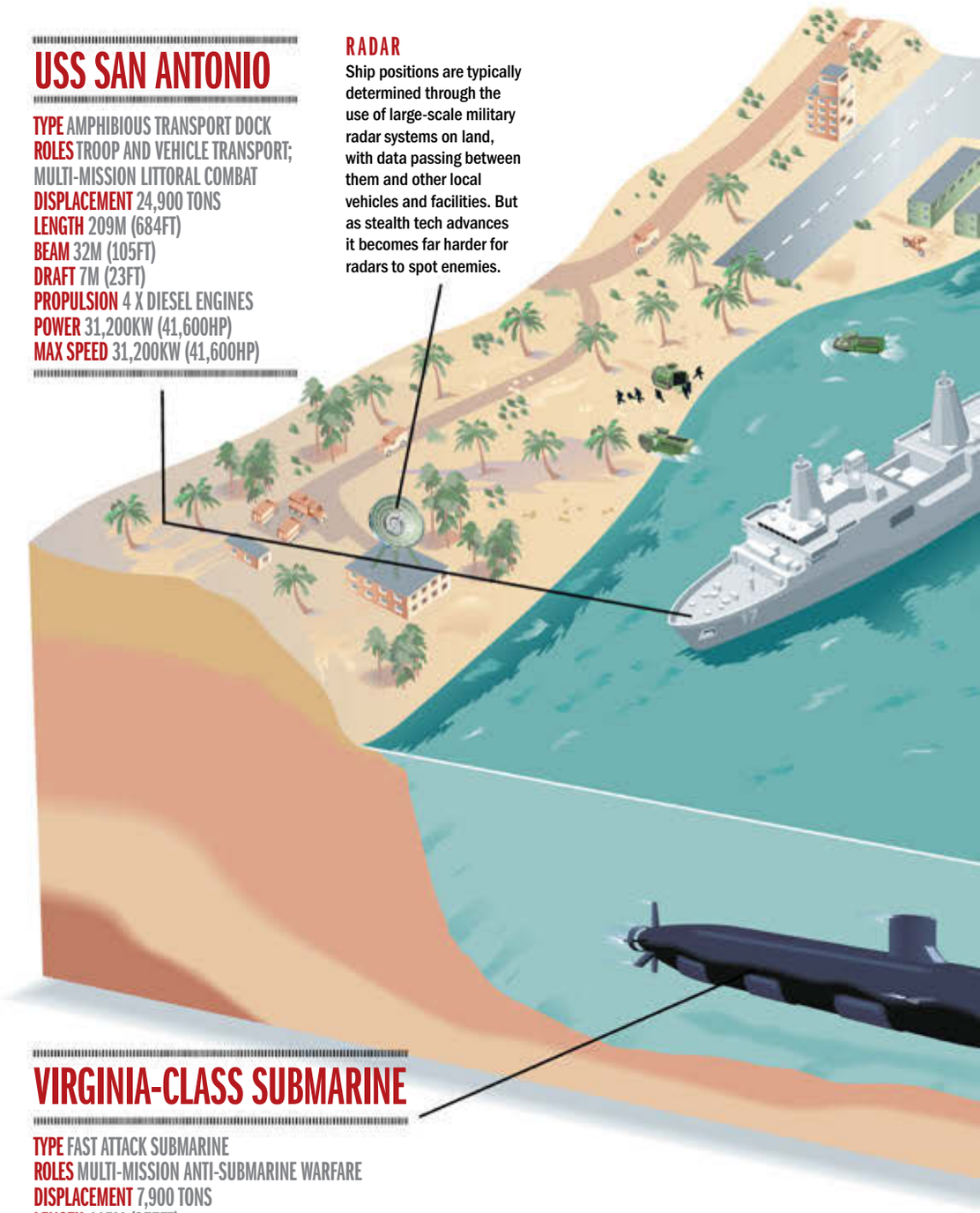
Noise in terms of maritime vessels can come courtesy of ship wake, heat generation and operating machinery. In fluid dynamics a wake is the area of disturbed liquid flow downstream of a ship. This wake can be detected by side-scanning synthetic aperture radars (SARs), which can then work out both the ship's position and direction plus sonar installations. To combat this, the latest stealth ships are generally outfitted with low-power diesel motors with specialised heat-dissipation systems to reduce their thermal signature. Active acoustic camouflage systems beneath the hull, meanwhile, can generate a constant series of small bubbles, effectively disrupting sonar images.

In this feature we explore four examples of cutting-edge military vessels that have been designed with covertness at the top of the priority list, from out-and-out destroyers through to agile, wraith-like submarines.

USS SAN ANTONIO

TYPE AMPHIBIOUS TRANSPORT DOCK
ROLES TROOP AND VEHICLE TRANSPORT; MULTI-MISSION LITTORAL COMBAT
DISPLACEMENT 24,900 TONS
LENGTH 209M (684FT)
BEAM 32M (105FT)
DRAFT 7M (23FT)
PROPULSION 4 X DIESEL ENGINES
POWER 31,200KW (41,600HP)
MAX SPEED 31,200KW (41,600HP)

RADAR
Ship positions are typically determined through the use of large-scale military radar systems on land, with data passing between them and other local vehicles and facilities. But as stealth tech advances it becomes far harder for radars to spot enemies.



VIRGINIA-CLASS SUBMARINE

TYPE FAST ATTACK SUBMARINE
ROLES MULTI-MISSION ANTI-SUBMARINE WARFARE
DISPLACEMENT 7,900 TONS
LENGTH 115M (377FT)
BEAM 10M (33FT)
PROPULSION 1 X S9G NUCLEAR REACTOR
POWER 29,828KW (40,000HP)
MAX SPEED 46KM/H (29MPH)

"TODAY'S VESSELS HAVE CLEAN AND ANGLED HULLS TO AVOID RADAR DETECTION"

MILITARY JET
Some jets are equipped with radar systems purposely designed to detect marine vessels. These systems can be foiled, however, by using radar jammers, stealth coatings and radomes.

USS ZUMWALT

TYPE DESTROYER
ROLES MULTI-MISSION LAND/SEA ATTACK
DISPLACEMENT 14,564 TONS
LENGTH 182.9M (600FT)
BEAM 24.6M (80.7FT)
DRAFT 8.4M (27.6FT)
PROPULSION 2 X ROLLS-ROYCE GAS TURBINES
POWER 78,000KW (104,600HP)
MAX SPEED 56KM/H (35MPH)

SATELLITE
All modern military vessels use a global positioning system (GPS) to help keep track of nearby vessels and to aid navigation.

LEGACY SUB
Old submarines did not specialise in stealth, relying purely on remaining underwater to stay hidden.

FISHING BOAT
This regular, small-scale fishing boat would generate a highly visible radar cross-section due to its lack of stealth technology and relatively complex shape.

TYPE 26 GLOBAL COMBAT SHIP

TYPE FRIGATE
ROLES MARITIME SECURITY; COUNTER PIRACY; TROOP DEPLOYMENT
DISPLACEMENT 5,400 TONS
LENGTH 148M (486FT)
BEAM 19M (62FT)
PROPULSION GAS TURBINES; DIESEL ENGINES
POWER UNKNOWN
MAX SPEED 51KM/H (32MPH)

The Type 26 is able to fool enemy radars thanks to its advanced damping equipment

TYPE 26 GLOBAL COMBAT SHIP

Capable of delivering cruise missiles, combat helicopters, unmanned hunter-killer drones and a barracks load of Royal Marines into coastal warzones, the new Type 26 Global Combat Ship from BAE Systems is set to deliver a platform for unprecedented covert operations at sea. Despite weighing about 5,400 tons and measuring a whopping 148 metres (486 feet) long (that's one and a half times the size of a football pitch), the Type 26 appears merely as a small fishing boat on radar systems. This means that when it becomes operational in 2021, it will be able to traverse the globe without detection and infiltrate hostile areas. The fishing boat-sized radar cross-section comes courtesy of the sleek, low-profile hull, specially angled deck panels, multi-installation radomes and advanced anti-radar/sonar damping equipment. This tech will cloak on-board vertical missile silos, an array of medium-calibre guns and a huge hangar containing both Merlin and Wildcat helicopters.

USS SAN ANTONIO

The USS San Antonio amphibious transport dock excels in its ability to efficiently carry and covertly deliver military vehicles and ground troops. This would not be so impressive if it wasn't for the size of the San Antonio, which weighs in at 25,000 tons – more than the Type 26 and USS Zumwalt combined!

So how is such a gargantuan vessel cloaked? Well, aside from the basics, it comes down to ship-wide attention to detail. Major antennas are mounted on platforms inside two advanced enclosed mast/sensor (AEM/S) systems rather than on yardarms. Deck edges are bounded by shaped bulwarks rather than lifeline stanchions; all exterior equipment is recessed or flush-mounted; bulky things like boat-handling cranes fold down when not in use; while the anchor and anchor hold are designed to minimise radar backscatter.

This strict adherence to stealth principles transforms the radar cross-section of what is essentially a small aircraft carrier into one under half its size. This allows it to sneakily approach target coastlines and launch air-cushioned landing crafts, amphibious assault vehicles, attack helicopters, military jeeps and even armoured personnel carriers onto land along with a maximum 699 soldiers.

Despite its enormous size, the USS San Antonio is still able to effectively cloak itself

THE USS SAN ANTONIO IN FOCUS

TAKE A LOOK AT SOME OF THIS WARSHIP'S MOST ADVANCED, STEALTH-ORIENTATED FEATURES

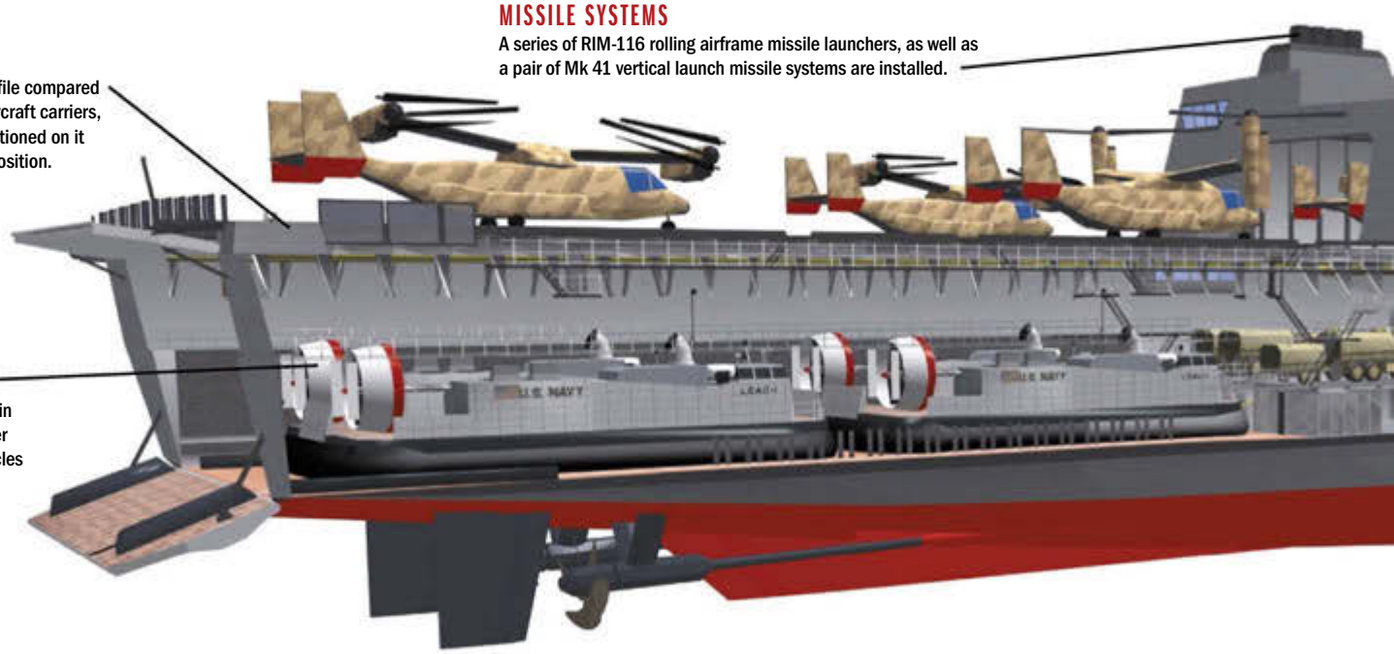
"THE USS SAN ANTONIO EXCELS IN ITS ABILITY TO CARRY AND COVERTLY DELIVER MILITARY VEHICLES AND TROOPS"

FLIGHT DECK

The Antonio's exposed flight deck has a low profile compared to those on full-blown aircraft carriers, enabling planesto be stationed on it without giving away its position.

MISSILE SYSTEMS

A series of RIM-116 rolling airframe missile launchers, as well as a pair of Mk 41 vertical launch missile systems are installed.



WELL DECK

As the San Antonio's main role is to stealthily deliver combat troops and vehicles onto coastal regions, an internal well deck is equipped with two LCAC landing crafts.

An array of stealth technology makes the USS Zumwalt almost invisible

USS ZUMWALT

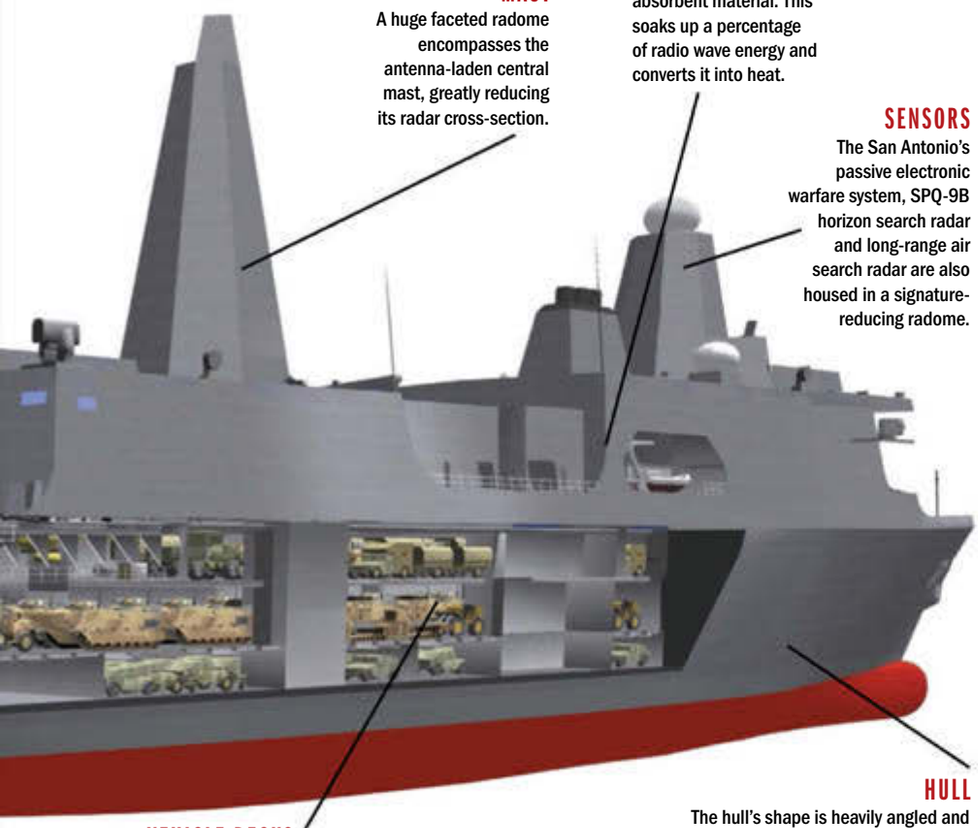
The USS Zumwalt doubles down on the Type 26's damage-dealing capabilities while maintaining a dedication to staying invisible. Stealth first. Features include an aluminium/glass-fibre composite structure, a wave-piercing hull that leaves almost no wake and an exhaust suppressor to reduce its infrared signature. On top of this, a high-angle inward sloping exterior, noise reduction system and a trapezoidal, radome-inspired command and control centre make this near-15,000-ton titan nothing but a ghost on radar. This arsenal of stealth technology allows it to silently slip through the waves, ready to inflict serious damage on unsuspecting targets.

The Zumwalt even extends its stealth mantra to its weapons, with every gun, missile and torpedo launched by integrated computer systems. As such, far from crew members having to man gun emplacements on deck or load missiles into launchers manually – generating more noise – the Zumwalt allows the sleek, minimal deck to remain undisturbed, so an offensive can be launched without compromising its location.

VIRGINIA-CLASS SUBMARINE

While the Type 26, USS Zumwalt and USS San Antonio are demonstrating advanced stealth technologies dedicated to reducing their cross-sections to radar, Virginia-class subs are utilising a piece of kit that can do the same for sonar. The Virginia's ultra-low acoustic signature comes courtesy of a special anechoic coating. The coating, which consists of a series of sound-absorbent, rubberised panels that sit on top of the hull, work by dampening electromagnetic waves, reducing the number that bounce back off the surface of the sub and sapping their overall energy. Adding to the Virginia's stealth ability is its revolutionary pump-jet propulsion, which works by drawing water into a turbine-powered pump via an intake then pushing it out at the rear, dramatically muffling noise.

Virginia-class subs muffle their noise output with the help of pump-jet propulsion



MAST
A huge faceted radome encompasses the antenna-laden central mast, greatly reducing its radar cross-section.

RAM COATING
The ship is coated in radar-absorbent material. This soaks up a percentage of radio wave energy and converts it into heat.

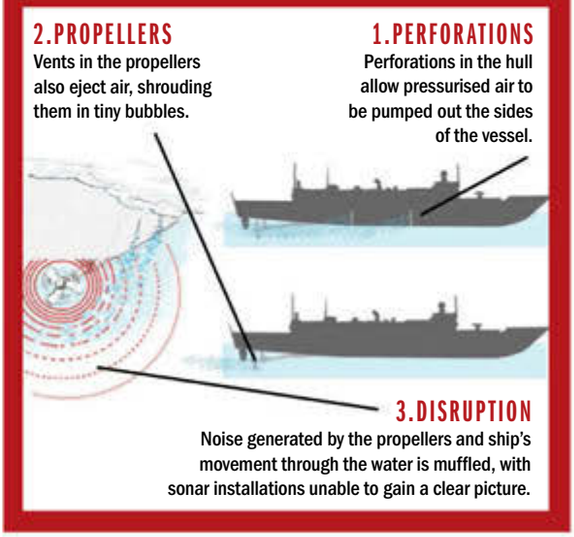
SENSORS
The San Antonio's passive electronic warfare system, SPQ-9B horizon search radar and long-range air search radar are also housed in a signature-reducing radome.

VEHICLE DECKS
Up to 14 expeditionary fighting vehicles and amphibious assault craft can be carried in the multi-tiered vehicle decks.

HULL
The hull's shape is heavily angled and sports few curved surfaces. These tailored angulations help massively to reduce the number of reflections bounced back to enemy radar installations.

WHAT ARE MASKING SYSTEMS?

Masking systems in marine vehicle applications work by reducing radiated noise generated by the vessel's propulsion system and general movement. This is achieved by mounting machined perforations on the sides and propellers of the ship, through which compressed air is pumped at a high rate. This action creates a barrier of tiny air bubbles around the vessel and propellers that traps mechanical noise and disrupts sonar waves. The result of this is that enemy sonar installations, such as those found on military submarines, receive a heavily distorted image of the scanned area, with vessels commonly shrouded in a pattern akin to rain falling on the ocean surface.



The British Type 45 has a displacement of 8,000 tons and can carry a crew of around 190

NEXT-GEN BATTLESHIPS

The firepower on the latest battleships is mind-boggling – we explore the technology transforming 21st-century naval warfare

If you thought that the golden age of naval combat came to an end 200 years ago, then clearly somebody forgot to tell the national navies of today, as a wave of state-of-the-art, armed-to-the-teeth battleships are currently emerging from shipbuilding yards around the world with a singular aim in mind: total domination of the seas.

From the brand-new and brutal Type 45 destroyers being pushed out of British dockyards, through to the almost sci-fi Zumwalt-class battleships emerging in the USA, and on to the cruising carrier vessels sitting like small islands in Earth's oceans, battleships are being produced en masse and to a more advanced spec than ever before.

Far from the basic heavyweights of bygone centuries, required simply to go toe-to-toe with each other in a deadly game of broadsides, today's warships need to take down a variety of threats, whether at sea, on land or in the air, and they need to do so at extreme range. As such, step onto a battleship today – be it a frigate, destroyer or corvette – and you'll find an arsenal of insane weapons systems.

There are cannons that can fire over distances of 95 kilometres (60 miles) and deliver a guided smart munition to a target with pinpoint accuracy, as well as Gatling guns that can automatically track a target moving at hundreds of miles per hour and then fire explosive bullets at up to 1,100 metres (3,610 feet) per second to take it down.

Missile launch systems not only increase the vessel's stealth but are capable of launching a wide variety of city block-levelling missiles directly into the heart of enemy encampments in minutes from a safe distance, while naval guns are capable of subjecting a target to continuous bombardment with high-explosive shells with controlled abandon. All this is but a taste of the weaponry being fitted to the most advanced 21st-century warships.

The heavy armament of vessels currently knows no bounds, with even coastguard fleets, convoy vehicles and civilian support ships being outfitted with some form of military-grade offensive weaponry. Clearly, controlling the world's waters is not as old-fashioned as the history books would have us believe. In this feature we take a look at the various types of battleship taking to the seas and the weapon systems that are revolutionising not just naval combat but warfare in general.

RULES OF ENGAGEMENT

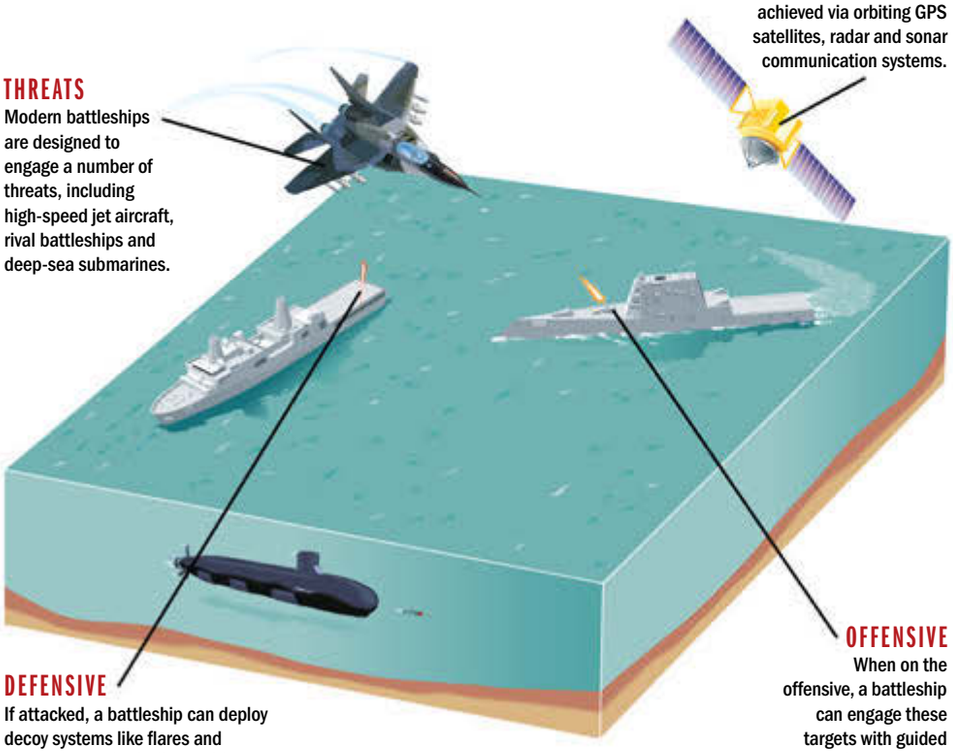
THE KEY STAGES AND TECHNOLOGY THAT DECIDE THE OUTCOME OF A MODERN NAVAL BATTLE

DETECTION

To engage any of these targets first they need to be detected – something achieved via orbiting GPS satellites, radar and sonar communication systems.

THREATS

Modern battleships are designed to engage a number of threats, including high-speed jet aircraft, rival battleships and deep-sea submarines.



DEFENSIVE

If attacked, a battleship can deploy decoy systems like flares and countering anti-missile munitions, or directly engage incoming threats with smart autocannons.

OFFENSIVE

When on the offensive, a battleship can engage these targets with guided or unguided missiles, explosive shells and deadly torpedoes.

A high-explosive guided torpedo is projected from a US battleship

More traditional 41cm (16in) naval guns on board the USS North Carolina

USS Iowa unloads a volley of explosive shells from its Mark 7 naval guns

BATTLESHIP TYPES

IT TAKES A RANGE OF DIFFERENT VESSELS TO HELP PATROL THE OCEANS

1 CORVETTE

One of the smallest types, the corvette is a lightly armed and manoeuvrable vessel used for coastal operations. Stealth corvettes are now becoming popular.

2 FRIGATE

Lightly armed, medium-sized ships generally used to protect other military or civilian vessels. Recently, frigates have been re-focused to take out submarines.

3 DESTROYER

Large and heavily armed, destroyers are typically outfitted for anti-submarine, anti-aircraft and anti-surface warfare, and can remain at sea for months on end.

4 CRUISER

The cruiser is an armed-to-the-teeth multi-role vessel akin to a modern destroyer. While cruisers are still in use, they have largely been superseded now.

5 CARRIER

Ocean-going leviathans, carriers are the largest type of battleship in existence. Their primary role is as a seagoing airbase, launching combat aircraft, but they also come heavily armed.

WEAPONS IN FOCUS

WE TRAIN OUR SIGHTS ON FOUR OF THE MOST ADVANCED ARMAMENTS ABOARD THE LATEST BATTLESHIPS

MK 110 NAVAL GUN

Capable of delivering automatic salvos of 220 57-millimetre (2.2-inch) Mk 295 Mod 0 ammunition every minute, the Mk 110 naval gun is a colossus. Stemming from one of the longest lasting naval gun series of the last century, the Mk 110 comes with a host of features. These include the ability to fire both standard and smart munitions, a gun barrel-mounted radar for measuring muzzle velocity, an instantaneous ability to switch ammunition types, a stealth-oriented ballistic shield that protects the gun while allowing a 360-degree traverse, plus a fully digital fire control system that enables the Mk 110 to respond to exact pointing orders and ammunition fuse selection milliseconds prior to firing. The only thing that stops the Mk 110 from bombarding its target continuously is its shell capacity, which rests at 120 rounds with a three-minute reload time.

ADVANCED GUN SYSTEM

The Advanced Gun System (AGS) is a naval gun from BAE Systems capable of firing precision munitions super-fast and at over-the-horizon ranges. Far from firing traditional unguided shells it fires the Long Range Land Attack Projectile (LRLAP), a 155-millimetre (6.1-inch) guided artillery shell that, thanks to base bleed rocket assistance and an extended range fin glide trajectory, can travel over 105 kilometres (65 miles) to a target. It then has a circular error probable of only 50 metres (164 feet), making it incredibly precise even at great distance. Throw in the fact that the AGS can fire ten LRLAPs per minute from its stealth-designed turret and that it can fire traditional unguided munitions as well and it becomes clear why it's being incorporated into many of today's warships.

The AGS is capable of hitting targets over 105 kilometres (65 miles) away

TURRET

The MK 110's turret is capable of a full-circle sweep and contains the gun's firing systems. The turret allows the gun to elevate from -10° through to +77° and is protected with a ballistic shield to disguise it from radars.

BARREL

The MK 110 has a single firing barrel with a progressive, 24-groove parabolic twist. The barrel's bore length is 3,990mm (157in), with the gun capable of firing 57mm (2.2in) conventional and smart munitions.

HOIST

The MK 110's 57mm (2.2in) Mk 295 Mod 0 ammunition is delivered to the turret emplacement via a mechanical loading hoist. Ammunition is stacked 120 rounds deep and automatically fed into the firing chamber.

VERTICAL LAUNCH SYSTEM

The Vertical Launch System (VLS) is a state-of-the-art multi-missile launching system. While previous systems could only fire one missile type, the VLS is modular so a variety of projectiles can be fired from the same enclosures. The missiles, which on Zumwalt-class destroyers include the RIM-162 Evolved Seasparrow missile, Anti-Submarine Rocket (ASROC) and Tactical Tomahawk subsonic cruise missile, are kept within the hull and, when launched, are fired from the top of the deck. By concealing missiles until needed, the VLS also improves the ship's radar cross-section. Each missile fired from a VLS cell is guided, with a selection of warheads directed to the target by radar or GPS.

"THE ADVANCED GUN SYSTEM CAN FIRE TEN OF THESE LRLAPS PER MINUTE FROM ITS STEALTH-DESIGNED TURRET"

PHALANX CIWS

Every new battleship comes with a close-in weapon system, and out of these systems the Phalanx CIWS is the best. It is a point-defence weapon designed to attack any target that has managed to evade the battleship's longer-range offensive weapons with its massive 20mm (0.8in) M61 Vulcan Gatling gun. It features an advanced targeting system, which consists of two independent antennas that work together to engage a target. The first is used to search for the target and delivers bearing, velocity, range and altitude information. The second tracks the target until it is in range. As soon as an incoming target is close enough, the Phalanx can automatically fire, using a selection of sensors to guide spent rounds at the unfortunate target in a split second.

RADAR

A bulbous tubular radome encases the Phalanx's Ku-band search and gun-laying radar. The search antenna sweeps for threats, and once a target is confirmed as hostile, the gun-laying antenna locks on.

GUN

Damage is dealt with a 20mm (0.8in) M61 Vulcan autocannon. The cannon has a muzzle velocity of over 1,100m/s (3,600ft/s) and an effective range of up to 3.6km (2.2mi).

DRUM

Ammunition for the Gatling cannon comes courtesy of a large magazine drum. This dispenser can feed the cannon at a rate of over 4,000 rounds per minute.

AIR

MIKOYAN MIG-29

168 The Russian fighter packs an incredible punch

C-130 HERCULES

152 Meet the biggest transport plane around

WESTLAND WASP

144 This chopper proves size doesn't always matter

124 Discover the fighters operated by air forces around the world

GLOBAL JETS

A-10 THUNDERBOLT II

150 Step on board the fearsome Warthog

V-22 OSPREY

170 Part chopper, part plane, the Osprey is the best of both

RECORD BREAKER

142 What made the F-4 Phantom II so revolutionary?

FIGHTER PLANES

Over 100 years of aerial combat has produced some of the most impressive and effective military technology

F-22 RAPTOR *1996*

Country: USA

A SPEED FREAK WITH AN ARSENAL TO MATCH

This current generation of fighter aircraft is only operated by the United States Air Force – no other nation can purchase the plane under Federal law. Designed to operate as a stealth attack aircraft, the F-22 has seen action in the Gulf and is capable of achieving incredible speeds of around 1,500mph.

VICKERS FB *1914*

Country: UK

THE UK'S FIRST FIGHTER PLANE

The Vickers was the first purpose-built fighter plane to be produced and was part of the world's first official fighter squadron. It came with two seats, a .303 Lewis gun and interestingly enough was only capable of speeds of around 70mph when at altitude.

POLIKARPOV I-15 *1934*

Country: Soviet Union

THE BACKBONE OF THE EARLY SOVIET AIR FORCE

The I-15 was used extensively from the 1930s to the mid-1940s by a selection of different nations. Flown by the Republicans during the Spanish Civil War, it remained in active service for many years, but was relegated to a ground-attack plane by 1941.

Corbis

MESSERSCHMITT BF 109 *1935*

Country: Germany

NAZI GERMANY'S ALL-CONQUERING TECHNICAL MARVEL

Perhaps the most-feared aircraft of the Second World War, the Bf 109 was the scourge of the skies on the Western Front. Early versions actually saw action during the Spanish Civil War, and over 30,000 had been produced by the end of the European theatre in 1945.

F-16 FIGHTING FALCON *1975*

Country: USA

AMERICA'S MULTI-PURPOSE KILLER BIRD OF PREY

Used by a multitude of nations, the F-16 became one of the most widely deployed attack aircraft in the final decades of the 20th Century. The fighter has enjoyed varying military applications since its inception, and carries with it a fearsome arsenal for engaging targets at sea, on land or in dogfights.

SOPWITH CAMEL *1916*

Country: UK

AN ICON OF THE SKIES OVER WWI EUROPE

A staple of the Royal Flying Corps during the First World War, the Sopwith Camel is perhaps the best-known aircraft of that era. Credited with a large number of confirmed kills, it became the most-prolific aircraft in Britain's arsenal, despite claims it was extremely difficult to fly.

TORNADO *1979*

Country: UK

STURDY BRITISH ENGINEERING AT ITS BEST

The Tornado was designed with both reconnaissance functionality and combat versatility in mind, with an array of features that enable it to perform effectively in all weather conditions, whether during the day or at night. It has seen action all over the world, notably during the First Gulf War.

5 Facts about FIGHTER PLANES

HESS TAKES FLIGHT

In 1941, deputy Führer Rudolph Hess hopped into a Bf 110 and flew to Scotland in an apparent attempt to open talks with Great Britain. The tail-end of his aircraft is on display at the Imperial War Museum.

DEATH FROM ABOVE

The monstrous GAU-8 cannon utilised by the A-10 Warthog generates so much recoil that if it weren't mounted off-centre it would actually pull the plane off course while firing.

WINGING IT

In 1983 an Israeli pilot actually managed to land his F-15 despite it only having one wing. Apparently he was unaware of the extent of the damage that had been done to his plane.

OUTNUMBERED AND OUTGUNNED

During the Second World War, an American P-51 fighter managed to hold off around 30 German fighters that were attempting to down a flight of B-17s. This lasted for over half an hour.

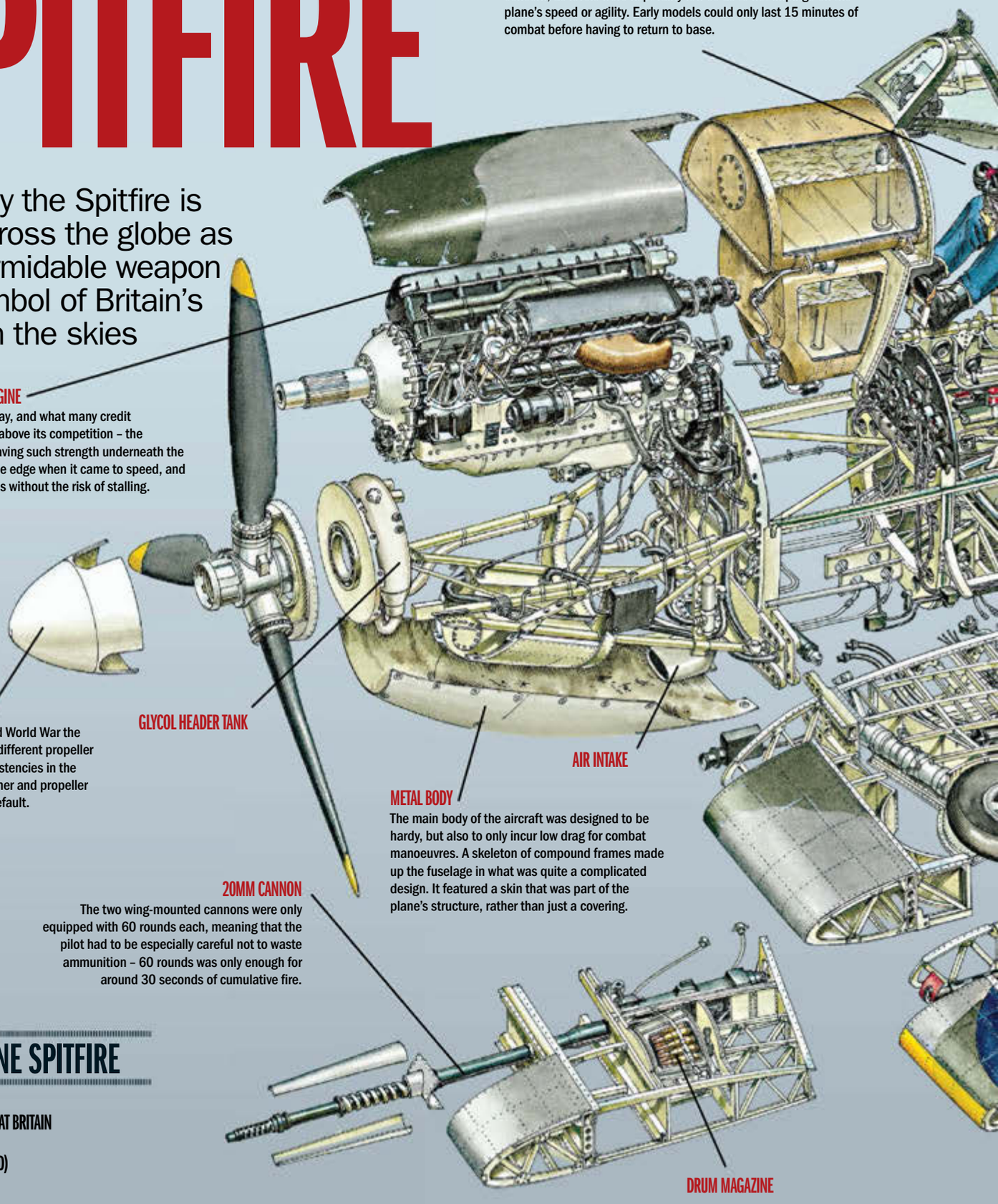
THE PLANE OF THE FUTURE

The Eurofighter Typhoon attack aircraft is so advanced that it requires a series of computers to keep it airborne – a human being cannot pilot the Typhoon without their support.

The Eurofighter Typhoon can reach a maximum velocity of Mach 2.0

ANATOMY OF A... SPITFIRE

To this day the Spitfire is known across the globe as both a formidable weapon and a symbol of Britain's triumph in the skies



STICK AND CONSOLE
As with all aircraft, the console enabled the pilot to monitor their air speed, altitude, fuel levels and more. Fuel was a particularly important concern, as levels were kept fairly low so as to not impinge on the plane's speed or agility. Early models could only last 15 minutes of combat before having to return to base.

ROLLS-ROYCE MERLIN ENGINE
This is where the power lay, and what many credit for boosting the Spitfire above its competition – the supercharged engine. Having such strength underneath the hood gave the Spitfire the edge when it came to speed, and enabled incredible climbs without the risk of stalling.

NOSE AND PROPELLER
By the end of the Second World War the Spitfire had enjoyed 13 different propeller designs. Despite inconsistencies in the design, though, the spinner and propeller setup was adopted by default.

GLYCOL HEADER TANK

AIR INTAKE

METAL BODY
The main body of the aircraft was designed to be hardy, but also to only incur low drag for combat manoeuvres. A skeleton of compound frames made up the fuselage in what was quite a complicated design. It featured a skin that was part of the plane's structure, rather than just a covering.

20MM CANNON
The two wing-mounted cannons were only equipped with 60 rounds each, meaning that the pilot had to be especially careful not to waste ammunition – 60 rounds was only enough for around 30 seconds of cumulative fire.

DRUM MAGAZINE

SUPERMARINE SPITFIRE

YEARS IN USE: 23
COUNTRY OF ORIGIN: GREAT BRITAIN
ENGINE SIZE: 1,470HP
WEIGHT: 2,300KG (LOADED)
LENGTH: 9.12M
TOP SPEED: 362MPH
WEAPONS: 2X 20MM CANNON, 4X .303 MACHINE GUNS

AERIAL MAST

COCKPIT AND CANOPY
Many pilots have spoken about being 'buried in a Spitfire', as being inside the cockpit is like falling into the bowels of the machine. The canopy was fixed and made of acrylic to offer the pilot a clear view of their surroundings. Earlier aircraft had employed glass panels for the cockpits, but these were more cumbersome and added extra weight to the plane.

HIGH-FREQUENCY TRANSMITTER

RUDDER AND TAIL SECTION
The Spitfire's central tail fin was longer than most, in order to provide more stability in the air when achieving the high speeds the aircraft was capable of. The rudder was stiff at high speeds, much like ailerons, requiring muscle to operate.

WIRELESS TRANSMITTER

TAIL WHEEL

THE FAMOUS INSIGNIA
These rings are the symbol of the Royal Air Force, and are known collectively as an emblem, called a roundel. The RAF roundel originated in World War One and served to identify the aircraft as being British – essential when in a hectic combat scenario.

ELLIPTICAL WING DESIGN
The wings of the Spitfire were designed with practicality and aerial agility in mind. By adopting a unique shape, the plane's wings were able to house armament and the landing gear when retracted, without sacrificing any of its enviable aerodynamics.

WING FLAPS
Unlike certain other fighter planes of the era, the flaps on a Supermarine Spitfire were only capable of being fully up or fully down. Flaps were lowered on approach for landing, with closed flaps more suitable for combat manoeuvres.

RETRACTED LANDING GEAR

AILERONS
As with most aircraft, the ailerons built into the wings were there to enable the aircraft to roll. Rolling has always been a key method of losing a pursuer in a dogfight, and combined with the Spitfire's high speed, the ailerons served as a strong line of defence against aggressors.

MACHINE GUN ARSENAL
Two .303 machine guns were mounted in each wing to support the heavier cannon fire, although again, ammunition was limited. Pilots were encouraged to fire in two- to three-second bursts to conserve rounds.

ICON OF THE SKIES
The Spitfire appeared at a crucial time. With the Luftwaffe running riot in the skies courtesy of Nazi Germany's early-war engineering efficiency, the Hawker Hurricane and P-40 were significantly lacking. The Spitfire changed the war, bringing with it exceptional power and manoeuvrability that outshone many of its contemporaries. It proved decisive in several key wartime sorties, racking up a raft of Luftwaffe kills and cementing itself as a far more popular and functional aircraft than the more-numerous Hawker Hurricane. Post-war it eventually served in different training roles until the 1950s – a testament to the joy of piloting it, its popularity as a machine, as well as its status as an emblem of power and respect.

Spitfires became iconic symbols in the Allied war effort – helping to defeat the previously untouchable Luftwaffe

DK Images, Corbis

FIGHTER PLANES OF THE WORLD

We salute the most iconic fighters from around the globe

1 LARGEST EVER DOGFIGHT

SYRIA 9 JUNE 1982

Nearly 200 fighter jets from Israel and Syria take to the skies and become embroiled in the largest air battle of all time. 80 Syrian planes are shot down.

Curtiss P-40

Produced: **1938**
Speciality: **Air superiority and ground attack**
Location: **USA**

JAS 39 Gripen

Produced: **1988**
Speciality: **Strikes and recon**
Location: **Sweden**

VL Myrsky

Produced: **1941**
Speciality: **Combat manoeuvres**
Location: **Finland**

P-51 Mustang

Produced: **1941**
Speciality: **High-speed attack fighter**
Location: **USA**

AV-8B Harrier II

Produced: **1978**
Speciality: **V/STOL strike aircraft**
Location: **United Kingdom**

Dassault Mirage

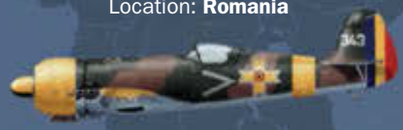
Produced: **1967**
Speciality: **Ground attack fighter**
Location: **France**

Fiat CR.42

Produced: **1938**
Speciality: **Single-seat biplane**
Location: **Italy**

IAR 80

Produced: **1941**
Speciality: **Ground attack aircraft**
Location: **Romania**



F2H Banshee

Produced: **1947**
Speciality: **Carrier-based jet fighter**
Location: **USA**

F-14 Tomcat

Produced: **1969**
Speciality: **Long-range interceptor**
Location: **USA**

2 RAIDING OCCUPIED FRANCE

DIEPPE, FRANCE 19 AUGUST 1942

As part of a major Allied counter-offensive into occupied France, 74 aerial squadrons support ground troops during the Dieppe Raid. It's a failure, with scores of Spitfires and Hurricanes lost.

Atlas Cheetah

Produced: **1986**
Speciality: **All-round strike aircraft**
Location: **South Africa**

3 SOVIET AIR SUPERIORITY

NORTH KOREA 12 APRIL 1951

Three squadrons of MiGs attack a flight of American B-29s in the midst of the Korean War without any Soviet losses. An embarrassed USAF christens the event Black Thursday.

MiG-29
Produced: **1977**
Speciality: **Short-range dogfighter**
Location: **Soviet Union**

HESA Saeqeh
Produced: **2004**
Speciality: **Air battles and bombing runs**
Location: **Iran**

Shenyang J-11
Produced: **1998**
Speciality: **Air superiority fighter**
Location: **China**

4 BRITISH HARRIERS ATTACK

FALKLAND ISLANDS 5 MAY 1982

Three Sea Harriers from HMS Hermes launch a key attack on the Argentine airfield at Goose Green on the Falkland Islands with cluster bombs and 1,000lb bombs. One aircraft is lost to anti-aircraft fire.

Ford Island was the epicentre of the Pearl Harbor attack

5 JAPAN STRIKES THE US

HAWAII 7 DECEMBER 1941

The Imperial Japanese Navy launches a surprise aerial attack on the US naval base at Pearl Harbor, sinking four Navy battleships and directly pressuring the US into intervening in the Second World War.

6 WWI AIR BATTLE

ST. MIHIEL, EASTERN FRANCE 12 SEPTEMBER 1918

British and French planes take to the skies over France to engage Germany in one of the first major air-to-air battles of all time.

Mitsubishi A6M Zero
Produced: **1939**
Speciality: **Long-range dogfighter**
Location: **Japan**

7 CIVILIANS UNDER FIRE

ZHONGSHAN, CHINA 24 AUGUST 1938

A Douglas DC-2, the Kweilin, is shot down over China by Japanese aircraft. There are three survivors of what is considered the first instance of a civilian liner being downed by a fighter plane.

8 DESERT STORM

IRAQ 17 JANUARY 1991

The first air-to-air victories of the First Gulf War are achieved. Two patrolling American F-15s shoot down and destroy two enemy Iraqi-operated MiG-29s. This is one of the first actions of Operation Desert Storm.

The Gulf War Allies send hundreds of planes into Iraq

FLYING A WWII PLANE

We get into the aircraft that trained pilots for World War II

It's the summer of 1940 and the German Luftwaffe is preparing to launch a mass air attack on Southern England. If they are victorious, Britain will be open to a land invasion and Blitzkrieg will be upon the British Isles. Luckily, brave and skilled RAF pilots take down the Messerschmitts in their Spitfires and Hurricanes, so the German Operation Sea Lion never materialises. But how were our pilots so skilled at air-to-air combat? We went down to Goodwood Flying School in West Sussex for a lesson way up in the sky almost exactly 74 years after the battle.

On a glorious day on the south coast, we will be over 1,200 metres (4,000 feet) in the air learning to fly like it's 1940. The plane taking flight here is not a Spitfire or a Hurricane; in fact it's not even a fighter at all. Instead it's the official World War II training plane for the RAF, the Harvard T-6, a Canadian-built Noorduyn model. Before we go skyward, we meet pilot Matt Hill who shows us the aviation ropes.

"The Harvard was used for advanced training, gunnery practice and blind flying, it had less speed and power than the Spitfire and the Hurricane as it was a trainer, not a fighter", Matt says, shortly after delivering a crash course on how to fly a plane. We're not going to be just a passenger on this particular flight – when we're in the air, we will actually have control of the plane.

Before we take to the skies it is important to know the history behind the aircraft. The Harvard was the second step in a RAF fighter pilot's training. Prior to this, a budding pilot would take to the skies in a Tiger Moth biplane. This aircraft would be used for a four-and-a-half-hour training session to hone the skills and art of flying before ramping up the power in the Harvard. Matt explains: "This plane (the Harvard) has a hydraulic system, brakes, a tail wheel and flaps, which the Tiger Moth doesn't. People who have flown the Mustang (US WWII fighter plane) say it is very, very similar." The Harvard was used by 30 countries as part of their respective air forces and the last military usage was as recent as 1995 in the South African armed forces.

"THE HARVARD HAD LESS SPEED AND POWER THAN A SPITFIRE AND THE HURRICANE AS IT WAS A TRAINER, NOT A FIGHTER"

HARVARD T-6 NORTH AMERICAN T-6 TEXAN

LENGTH 8.5M (28FT)
WINGSPAN 12.8M (42FT)
SEATING TANDEM
POWER 450KW (600HP)
ENGINE PRATT & WHITNEY R-1340 WASP
PROPELLER HAMILTON STANDARD TWO-BLADE 12D40 PROPELLER
TOP SPEED 338KM/H (210MPH)

A fleet of T-6s in 1941 ready for training drills at Randolph Field, Texas

RAF FIGHTER ACES DURING THE BATTLE OF BRITAIN

NAME	AIRCRAFT	KILLS
PILOT OFFICER ERIC LOCK	SPITFIRE	21
FLIGHT LIEUTENANT ARCHIE MCKELLAR	HURRICANE	19
SERGEANT JAMES LACEY	HURRICANE	18
SERGEANT JOSEF FRANTIŠEK	HURRICANE	17
FLYING OFFICER WITOLD URBANOWICZ	SPITFIRE	15

A Goodwood Flying School pilot shows us the ropes

Our pilot all dressed up and ready to go

On inspection of the Harvard, it is obvious this striking machine is almost entirely unchanged since the 1940s. In fact, a fresh coat of paint is literally the only difference. The first production model flew in 1938 and its successful test flight convinced the British to order over 300 for training purposes. Far from a relic, the original instruments are all still in complete working condition and the dual cockpits are exactly how they would have been in the war. With that, Matt calls an end to the chitchat as the runway beckons. The Top Gun-esque suit is donned and into the skies we go.

The flight itself lasted 40 minutes. First, we undertook a circuit of the airfield and witnessed some breathtaking views of the nearby towns of Chichester and Bognor Regis. There wasn't much time to take in the sights, however, as it was now our turn to take the reins. Matt prepared the plane for a change in control by maintaining a steady speed and making the plane level. With a slight shunting motion, the craft was now in our hands. The Harvard is controlled by a central stick which you move in the direction you want the plane to go. The stick was incredibly sensitive and a slight movement to either side would alter the plane's flight path considerably. It felt very tense being in a tiny vehicle in a huge expanse of sky.

After the short solo journey, it was time to relinquish control and hand over to Matt, who would now do some extreme aerobatic manoeuvres. We began with a full loop, which gave the experience of around 3g's worth of force. Next up was the barrel roll, which was followed by twists and dives that resulted in a similar amount of g-force. The only way to describe the feeling is to imagine the biggest and fastest roller coaster you've been on and then multiply it by ten.

Leaving Goodwood, you couldn't help but wonder how the RAF performed these amazing moves, all while engaging in heated aerial warfare with the mighty Luftwaffe. It boggles the mind that these brave men did this just a touch over 70 years ago, too. Even today, though, the Harvard T-6 stands out as a wonderful machine and was undoubtedly a key component in the RAF having the skill to win the Battle of Britain and halt the German advance.

THE HARVARD'S MODERN COUSIN

On the day, we also had the chance to test out another plane, the Cessna 172S Skyhawk, which is one of the planes used currently to train new pilots. However, the one most like the Harvard is the Swiss-built Pilatus PC-21. Used to train modern-day fighter pilots, the PC-21 provides an ideal introduction to flying jet-based fighters. It can be used for both beginner and advanced training, using a turboprop engine that uses a propeller flown by a turbine. It can reach speeds of up to 685 kilometres (425 miles) per hour and current customers include the air forces of Singapore, United Arab Emirates and the Royal Saudi Air Force.

The Cessna 172S Skyhawk, a new training plane

THE HARVARD: INSIDE AND OUT

A TRIP AROUND THE T-6 AND ITS MAIN FEATURES

COCKPITS
The Harvard contains two cockpits; one for the pilot and one for the learner. Both have very similar instrument panels and the learner solo control can be engaged at any time.

CRUISING SPEED
Although the top speed is slightly higher, the Harvard generally cruised at around 230km/h (145mph) at an ideal altitude of 2,440m (8,000ft).

RANGE
On a full tank and in good conditions, the plane can fly up to 1,175km (730mi). That's further than from John o' Groats to Land's End!

***Below:** The front propeller gives it an imposing appearance*

"WE BEGAN WITH A FULL LOOP, WHICH GAVE THE EXPERIENCE OF AROUND 3G'S WORTH OF FORCE"

IN ACTION
In the war the T-6 could also function as a FAC (forward air controller) to support frontline troops by surveying the local area.

CONTROL
Steering is done using the centre stick, although differential braking in the tailwheel can be used as well.

ARMAMENT
Although strictly a training plane, the Harvard could hold light machine guns on its wings and could even include bomb racks.

ALTITUDE
The Harvard can be stretched to a service ceiling of 7,376m (24,200ft) before the elevation is too high for its instruments and mechanisms to cope.

HYDRAULIC SYSTEM
Activated by a push of a button, the system allows you to use the gears and flaps on the plane.

ON THE TIGER MOTH BIPLANE

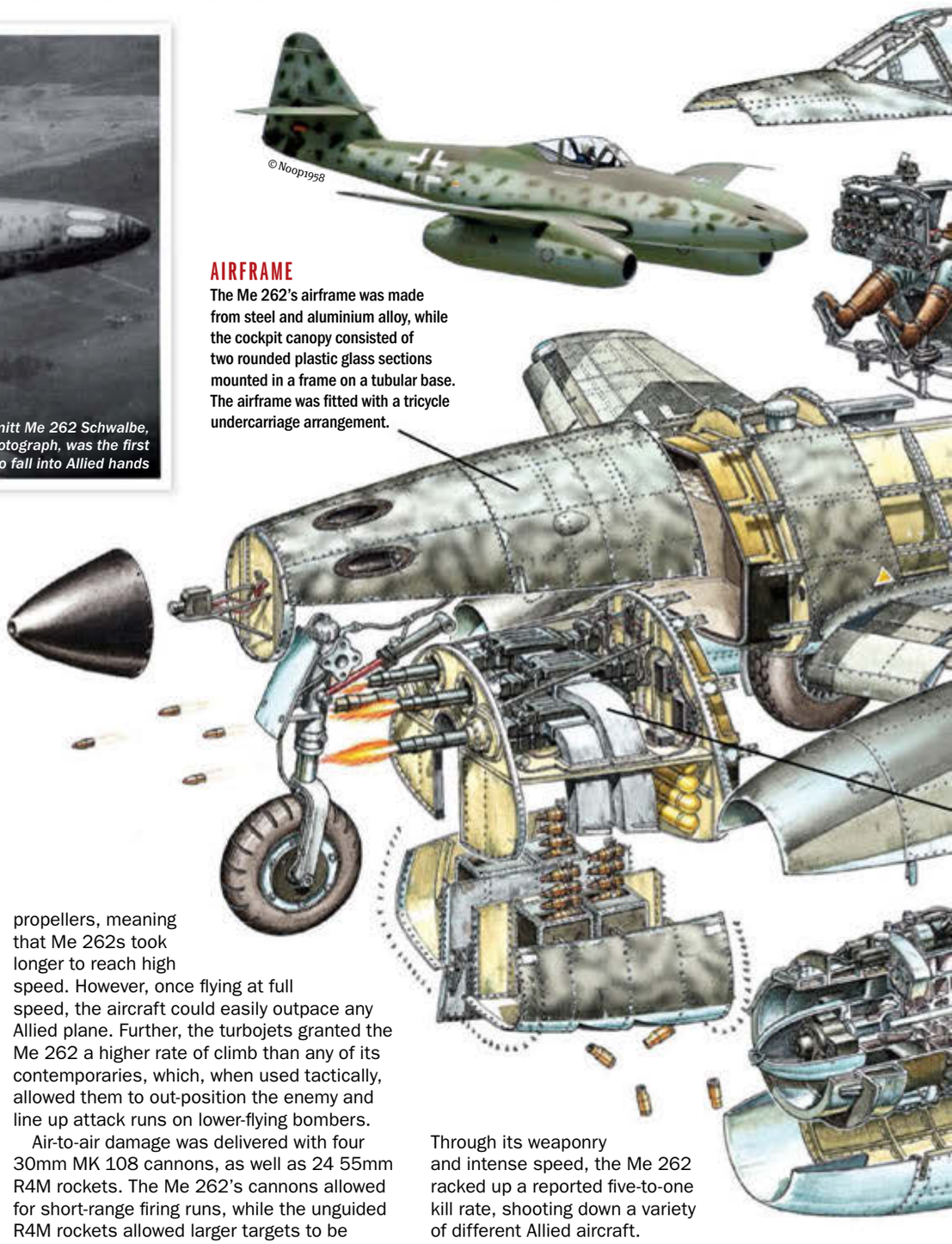
A trip on a Tiger Moth is very different to a Harvard flight. As it's a biplane, flights are completed at a much lower altitude and at considerably slower speeds. This is ideal for the beginner pilot to understand the controls before ramping the difficulty up to the Harvard. The controls in the biplane are less responsive than most, so piloting it is actually pretty tricky. The RAF liked this quality as it quickly separated the talented pilots from the rest. The 'Moth' is a semi-aerobatic plane, so it can still loop and barrel roll, which made it an ideal starter plane for RAF training.

The Tiger Moth served as a preliminary training plane

MESSERSCHMITT ME 262

How this German fighter aircraft brought terrifying speed and combative dominance to the aerial battlefields of World War II

The Messerschmitt Me 262 Schwalbe, as seen in this photograph, was the first variant of the jet to fall into Allied hands



Speed kills. This is a fact of war that the Nazi regime understood well, employing it to great effect with their 'Blitzkrieg' (lightning war) tactics of WWII, puncturing holes in Allied lines with great speed and firepower. It was a mantra they incorporated into all aspects of their military and, as shown in the groundbreaking Messerschmitt Me 262 fighter jet, often generated spectacular results.

The Me 262 was the most advanced aviation design brought to fruition during World War II, and the first ever operational jet-powered fighter aircraft in the world. It featured a state-of-the-art, streamlined steel and aluminium alloy chassis, twin super-powerful Junkers Jumo 004 B-1 turbojet engines and a suite of weaponry that allowed it to fulfil a wide variety of roles in combat. It was originally conceived to be a high-speed fighter-interceptor used to take down Allied bombers during sorties (flight missions), however under order from Adolf Hitler himself, its role was widened to also include bombing duties.

Its aerial dominance rested on its high top speed of 900km/h (560 mph), which obliterated its nearest rivals, the American P-51 Mustang and British Spitfire. Indeed, the extreme velocity that the Me 262 brought to the aerial battlefield meant that traditional dog-fighting tactics needed to be rewritten, with Allied pilots unable to track the aircraft with their electric gun turrets or tail them over long stretches. Instead, Allied pilots had to gang up and attempt to force the 262's pilot into making low-speed manoeuvres, from which it could be shot down.

This formidable power came from the fighter's turbojets. They didn't provide as much thrust at lower speeds than that of propellers, meaning that Me 262s took longer to reach high speed. However, once flying at full speed, the aircraft could easily outpace any Allied plane. Further, the turbojets granted the Me 262 a higher rate of climb than any of its contemporaries, which, when used tactically, allowed them to out-position the enemy and line up attack runs on lower-flying bombers.

Air-to-air damage was delivered with four 30mm MK 108 cannons, as well as 24 55mm R4M rockets. The Me 262's cannons allowed for short-range firing runs, while the unguided R4M rockets allowed larger targets to be peppered with high-explosive munitions, each one capable of totally destroying any aircraft of the day. Air-to-ground attacks were actualised through a selection of 250kg or 500kg (550lb to 1,100lb) free-fall bombs, which were stored and released from dedicated bomb bays.

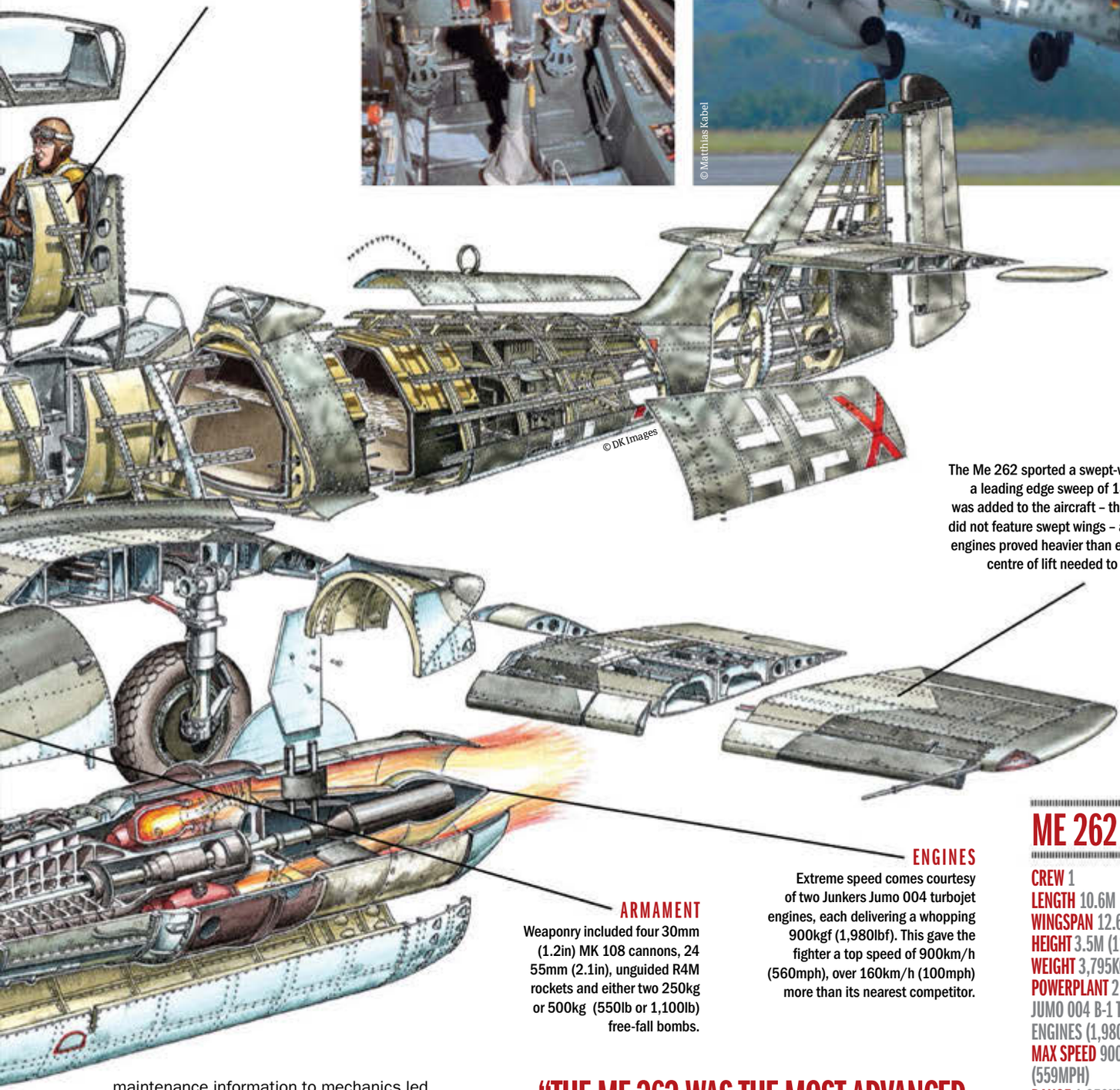
Through its weaponry and intense speed, the Me 262 racked up a reported five-to-one kill rate, shooting down a variety of different Allied aircraft.

Unfortunately, the reign of the Me 262 was short-lived, as mass delays in bringing it to operational functionality meant that it was not introduced until the spring of 1944, just over a year before the close of the war. Further, poor parts availability and dissemination of

The Me 262's engines allowed a top speed of 900km/h

INSTRUMENTATION

Flight instruments in the Me 262's cockpit included an artificial horizon, bank and turn indicators, airspeed indicator, altimeter, rate of climb indicator, repeater compass and blind approach indicator.



WINGS

The Me 262 sported a swept-wing profile, with a leading edge sweep of 18.5°. This sweep was added to the aircraft – the original design did not feature swept wings – as the Jumo 004 engines proved heavier than expected and the centre of lift needed to be repositioned.

ARMAMENT

Weaponry included four 30mm (1.2in) MK 108 cannons, 24 55mm (2.1in), unguided R4M rockets and either two 250kg or 500kg (550lb or 1,100lb) free-fall bombs.

ENGINES

Extreme speed comes courtesy of two Junkers Jumo 004 turbojet engines, each delivering a whopping 900kgf (1,980lbf). This gave the fighter a top speed of 900km/h (560mph), over 160km/h (100mph) more than its nearest competitor.

ME 262 A-1A

CREW 1
LENGTH 10.6M (34.8FT)
WINGSPAN 12.6M (41.5FT)
HEIGHT 3.5M (11.5FT)
WEIGHT 3,795KG (8,367LB)
POWERPLANT 2 X JUNKERS JUMO 004 B-1 TURBOJET ENGINES (1,980LBF EACH)
MAX SPEED 900KM/H (559MPH)
RANGE 1,050KM (652MI)
MAIN ALTITUDE 11,450M (37,566FT)
ARMAMENT 4 X 30MM MK 108 CANNONS, 24 X 55MM R4M ROCKETS, 2 X 250KG BOMBS

maintenance information to mechanics led to serious deficiencies in fleet fly time, with few aircraft ever in the air at any one time. Due to its overwhelming aerial dominance, Allied forces soon identified the Me 262's potential threat and dedicated large quantities of bombing sorties to destroying construction factories and launch bases.

"THE ME 262 WAS THE MOST ADVANCED AVIATION DESIGN BROUGHT TO FRUITION DURING WORLD WAR II, AND THE FIRST OPERATIONAL JET-POWERED FIGHTER"

B-17 FLYING FORTRESS

A key weapon used by the allied air forces to take down the industrial might of Germany in WWII

The B-17 was initially designed in 1934 by Boeing to take part in a US Army Air Corps competition to produce a modern multi-engined bomber. The company's Model 299 prototype first flew on 28 July 1935, and a journalist at the time nicknamed it the 'Flying Fortress' on account of its size and sturdiness.

In October 1935, the prototype crashed and the design ultimately lost out to the Douglas DB-1. Fortunately, the Air Corps recognised it was still a promising aircraft and ordered 13 299s in January 1936, which they designated the Y1B-17. Not long after, the Y1B-17 became the B-17, and Wright Cyclone engines were added to replace the 299's Pratt & Whitney Hornet engines.

In 1938, another big advance arrived in the introduction of turbo super-chargers to the engines of a B-17A test aircraft that could take it to an altitude of 9,144 metres (30,000 feet). The B-17B became the first production model, but at the outbreak of World War II, only 30 of them were in an operational state. In 1940, 38 B-17Cs were built with better-armoured protection, and only 42 B-17Ds were rolled out before mass production of the redesigned B-17E, B-17F and the ultimate B-17G models. Out of the total production run of 12,725 B-17s, 512 were E-class, 3,400 were F-class and 8,680 were G-class.

To fulfil its promise as a precision strategic bomber, it was fitted with the top-secret Norden bombsight. This was a gyroscope-stabilised device that calculated the dropping angle and drift of the aircraft to enable accurate high-altitude bombing.

The B-17 gained a deserved reputation for being able to sustain high levels of damage, as well as being capable of being brought back to land by relatively inexperienced crew members when necessary.

It is believed that around 5,000 B-17s were shot down or destroyed in their various missions to eliminate industrial and military targets during WWII.

The B-17 has starred in a number of films, including Twelve O'Clock High (1949) and the more modern Memphis Belle (1990)

NOSE COMPARTMENT

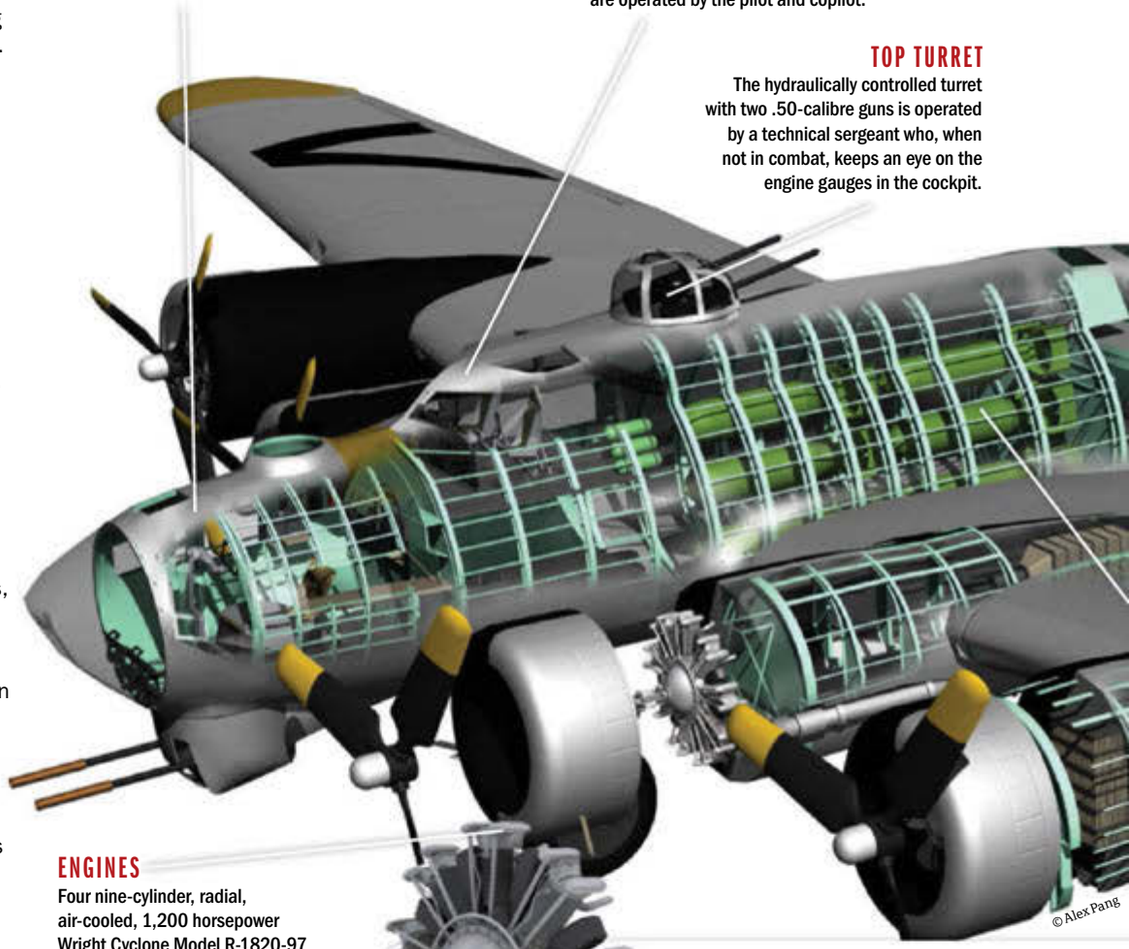
The bombardier perches inside the nose to operate the Norden bombsight and release the payload. The navigator sits behind him.

CONTROLS AND INSTRUMENTS

The instrument panel and controls feature 150 handles, gauges, dials, switches and cranks that are operated by the pilot and copilot.

TOP TURRET

The hydraulically controlled turret with two .50-calibre guns is operated by a technical sergeant who, when not in combat, keeps an eye on the engine gauges in the cockpit.



© Alex Pang

ENGINES

Four nine-cylinder, radial, air-cooled, 1,200 horsepower Wright Cyclone Model R-1820-97 engines power the 3.6m (11.7ft)-diameter three-bladed propellers.

B-17 UPDATES

The B-17 went through a range of modifications in line with experience and mission requirements. Its range could be extended with additional fuel tanks, and it could carry more bombs on external racks. Defensive weaponry on the craft was revised on various models, with powered turrets and additional gun slots introduced. Ammunition weight meant that each gunner got 500 rounds that would give one minute of constant fire. Despite being a 'flying fortress' it needed fighter aircraft escorts to give it protection during daylight raids.

During attacks B-17s tended to fly in a wedge formation for greater protection

"THE B-17 GAINED A REPUTATION FOR BEING ABLE TO SUSTAIN HIGH LEVELS OF DAMAGE"

TACTICS

The US 8th Air Force began using B-17Es in daylight raids on Nazi-occupied Germany. The extra visibility afforded by daylight allowed for precise bombing of the targets and promised to be more successful in the long run than night-time raids.

Their first attack on Germany occurred on 27 January 1943, which consisted of a force of 91 B-17s and B-24s. It was found that the B-17s could protect themselves from cross-fire and attacking fighters by flying in wedge-shaped formations, but they were very vulnerable to head-on attacks.

A year later, the improved B-17G carried chin turret machine guns. Instead of flying in wedges of 18 aircraft, they now flew in a formation of three, stacked wedges, with 12 aircraft in each. Though this offered more protection from enemies, it meant collisions between the tightly packed aircraft were increased.

WAIST GUNNERS

The waist gunners fire through open windows either side of the open-plan fuselage.

The B-17 on a bomb run

RADIO OPERATOR

The radio operator has a self-contained compartment and a .50-calibre machine gun above him. When fitted with radar the radar navigator sits in front of the radio operator.

TAIL GUN

A track feeds ammunition from a magazine in the body of the aircraft to the two M2 .50-calibre machine guns in the cramped turret.

BALL GUN TURRET

The Sperry Plexiglas, hydraulically controlled ball gun turret is 76cm (30in) in diameter, and the gunner can only view the target between his legs. In fact, space is so limited his parachute has to be kept inside the aircraft.

B-17 FLYING FORTRESS

CREW 10
WINGSPAN 31.6M (103.9FT)
HEIGHT 5.8M (19.1FT)
POWER 4 X WRIGHT CYCLONE ENGINES
MAX SPEED 462KM/H (287MPH)
RANGE 5,471KM (3,400 MILES)
MAX ALTITUDE 10,850M (35,600FT)
ARMAMENT 13 BROWNING M2 MACHINE GUNS
BOMB LOAD 2,724KG (6,000LBS)

BOMB BAY

Bombs are stacked from floor to ceiling in racks, with a catwalk between them. Crew members have to manually crank open or close the bomb bay doors if they malfunction or are damaged.

AIRFRAME

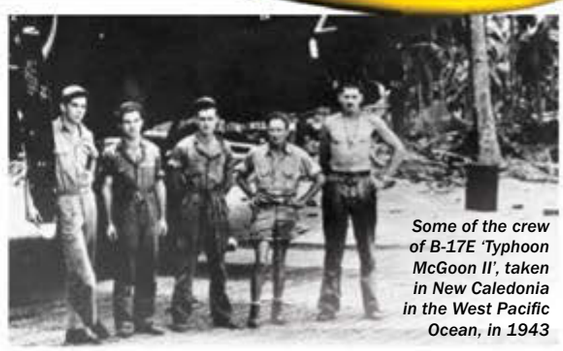
The body is given shape and strength by aluminium ribs held together by rivets and bridge-like zigzag braces.

OPERATIONAL HISTORY

The B-17 was conceived as a coastal defence weapon or strategic day bomber, so when the RAF was supplied with 20 B-17Cs in 1941 they were unimpressed by its inability to bomb accurately above 6,096 metres (20,000 feet) and its lack of armour. 90 Squadron used the aircraft in the Middle East and for reconnaissance missions by Coastal Command.

The majority of B-17s were used by the US 8th Air Force to fight the war in Europe. Some B-17s were deployed in the Far East and South Pacific where they were involved in bombing Japanese convoys and troop concentrations. In the Mediterranean and North Africa, B-17s attacked naval targets and took part in night-time reconnaissance.

After the war, B-17s were modified to carry passengers or cargo, or to fight forest fires or carry out photographic surveys. The Israeli Air Force used a small number in the 1948 War of Independence and the US Army Air Force used them for testing equipment, target drones and weather reconnaissance.



Some of the crew of B-17E 'Typhoon McGoon II', taken in New Caledonia in the West Pacific Ocean, in 1943

LANCASTER BOMBER

Famed for its prowess and entrenched in popular culture by The Dam Busters film of 1955, the Lancaster bomber played a vital role in securing an allied victory in World War II

Arguably the most famous heavy bomber of World War II, the Avro-built Lancaster bomber undertook some of the most dangerous and complex missions yet encountered by the RAF. Primarily a night bomber but frequently used during the daytime too, the Lancasters under Bomber Command flew some 156,000 sorties during the war, dropping 609,000 tons of bombs. Among these bombs was the famous 'bouncing bomb' designed by British inventor Barnes Wallis, a payload that would lead the Lancaster to remain famed long after 1945. How It Works takes a look inside a Avro Lancaster to see what made it so successful.

Lancaster bombers dropped 609,000 tons of bombs

INSIDE A LANCASTER BOMBER

LANCASTER BOMBER

CREW 7
LENGTH 21.18M
WINGSPAN 31.09M
HEIGHT 7.3M (24FT)
WEIGHT 29,000KG
POWERPLANT 4 X ROLLS-ROYCE MERLIN XX V12 ENGINES
MAX SPEED 280MPH
MAX RANGE 3,000 MILES
MAX ALTITUDE 8,160M
ARMAMENT 8 X .7.7MM BROWNING MACHINE GUNS; BOMB LOAD OF 6,300KG

CREW

Due to its large size, hefty armament and technical complexity, the Lancaster bomber had a crew of seven. This included: a pilot, flight engineer, navigator, bomb aimer, wireless operator, mid-upper and rear gunners. Many crew members from Lancasters were awarded the Victoria Cross for their heroic actions in battle, a notable example being the two awarded after a daring daytime raid on Augsburg, Germany.

BOMB BAY

The bomb bay could carry a great payload. Indeed, the bay was so spacious that with a little modification it could house the massive Grand Slam "earthquake" bomb, a 10,000kg giant that when released would reach near sonic speeds before penetrating deep into the Earth and exploding.

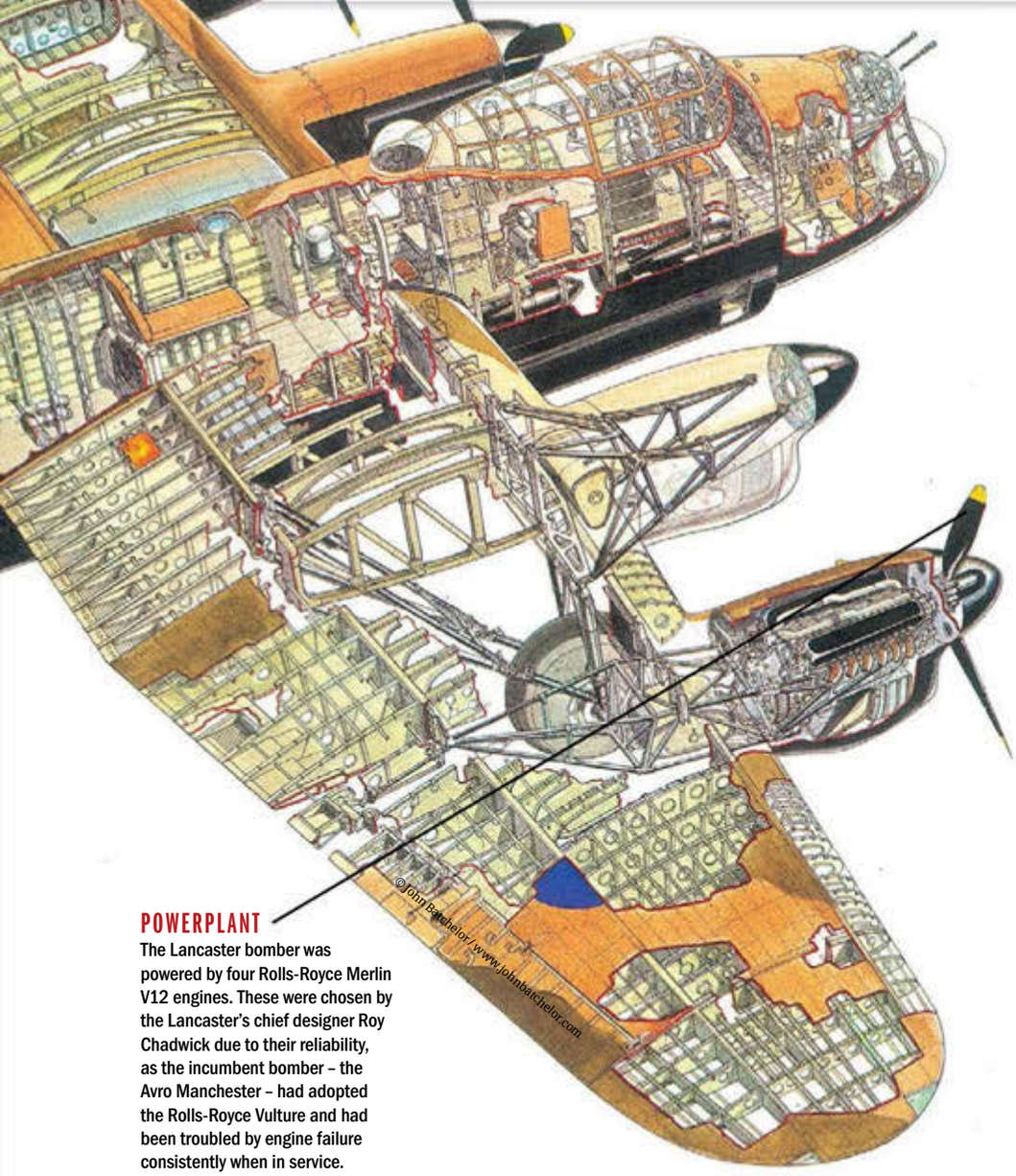
TURRETS

As standard the Lancaster bomber was fitted with three twin 7.7mm turrets in the nose, rear and upper-middle fuselage. In some later variants of the Lancaster the twin 7.7mm machine guns were replaced with 12.7mm models, which delivered more power. The rear and upper-middle turrets were staffed permanently by dedicated gunners, while the nose turret was staffed periodically by the bomb aimer when caught up in a dogfight.

FUSELAGE

The Lancaster was designed out of the earlier Avro Type 683 Manchester III bomber, which sported a three-finned tail layout and was similar in construction. While the overall build remained similar the tri-fin was removed in favour of a twin-finned set up instead. This is famously one of only a small number of design alterations made to the bomber, which was deemed to be just right after its test flights.


Over 7,000 bombers were built



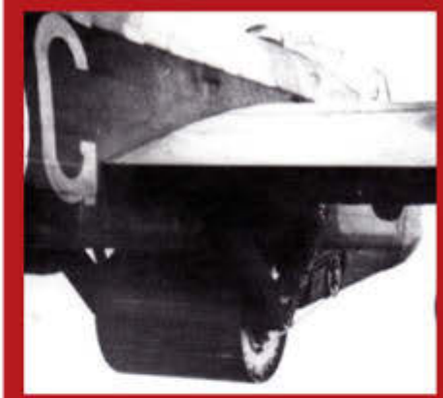
POWERPLANT

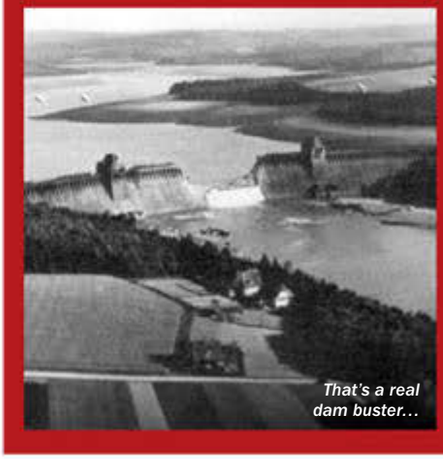
The Lancaster bomber was powered by four Rolls-Royce Merlin V12 engines. These were chosen by the Lancaster's chief designer Roy Chadwick due to their reliability, as the incumbent bomber – the Avro Manchester – had adopted the Rolls-Royce Vulture and had been troubled by engine failure consistently when in service.

THE BOUNCING BOMB

One of the most famous parts of the Lancaster's heritage is its role in carrying and releasing the 'bouncing bomb' payload, as glamourised in the 1955 film The Dam Busters. The bomb was designed by Barnes Wallis – who was also the creator of the Grand Slam and Tallboy bombs – and was special in its ability to bounce along the top of a surface of water, much akin to skimming a stone. It was designed to counteract and evade German defences below and above the waterline, allowing Allied forces to target German hydroelectric dams and floating vessels.

In May 1943 the bouncing bombs were utilised in Operation Chastise, an allied mission to destroy German dams in the Ruhr Valley. The aircraft used were modified Avro Lancaster Mk IIIs, which had much of their armour and central turret removed to accommodate the payload. Despite eight Lancasters being lost during the operation, along with 53 crew, a small number of bouncing bombs were released and they caused two dams to be breached, one to be heavily damaged and 1,296 civilians to be killed.




That's a real dam buster...

F-86 SABRE

Considered the foremost military aircraft of the Fifties, the F-86 Sabre was a highly versatile fighter jet as fast as it was lethal

The F-86 Sabre was a single-seat fighter jet built by North American Aviation (now part of Boeing) in the late-Forties. The aircraft – the first western jet ever to feature swept wings, as well as one of the first aircraft in the world to be capable of breaking the sound barrier in a dive – saw military action throughout the Korean War and Cold War.

Built initially to combat the Russian MiG-15, the Sabre was geared towards flight superiority roles, dispatched to undertake furious high-speed dogfights. Though inferior to the Russian jet in terms of lightness and weaponry, the reduced transonic drag delivered by the swept wings – combined with its streamlined fuselage and advanced electronics – granted it far superior handling. This ability to outmanoeuvre the MiG-15 soon saw it establish supremacy in combat.

Despite possessing an overall armament inferiority to its rivals, the Sabre was one of the first military jets capable of firing guided air-to-air missiles and later variants, such as the F-86E, were additionally fitted with radar and targeting systems that were revolutionary for the time. These factors, along with its high service ceiling (ie maximum altitude) and its generous range of around 1,600 kilometres (1,000 miles), therefore enabled it to intercept any enemy aircraft with ease.

However, today the Sabre is most known for its world record-breaking performances, with variants of the jet setting five official speed records over a six-year period in the Forties and Fifties. Indeed, the F-86D made history in 1952 by not just setting the overall world speed record (1,123 kilometres/698 miles per hour), but then bettering it by an additional 27 kilometres (17 miles) per hour the following year.

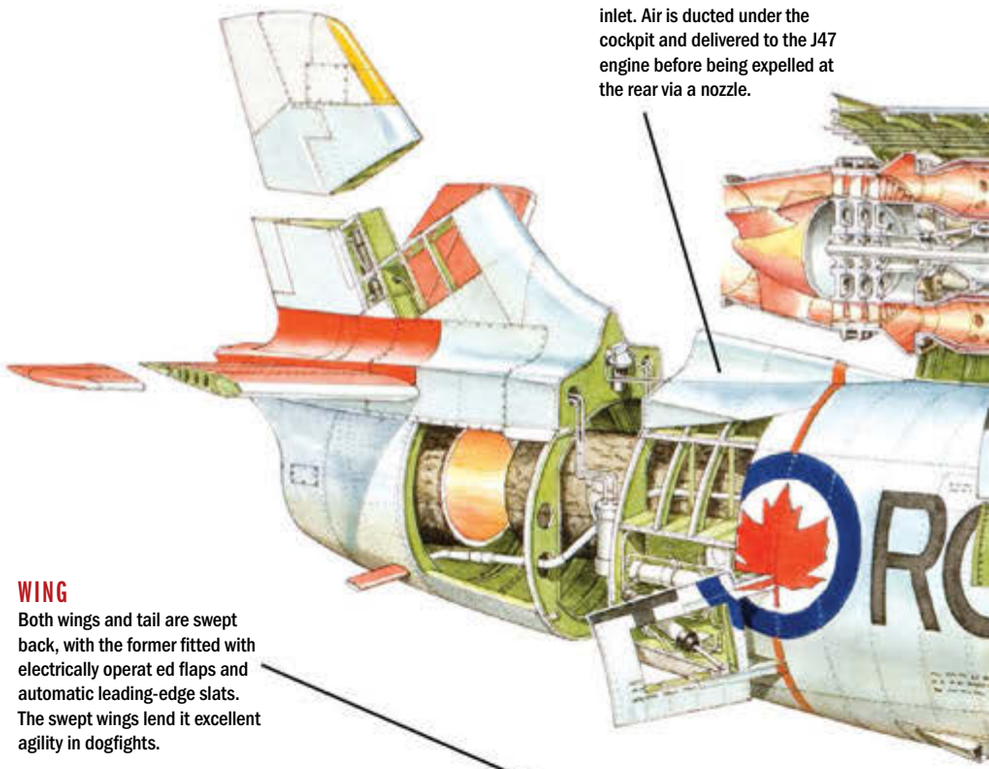
Today there are no F-86s remaining in service in national militaries, but due to their iconic status and reliable handling, many do remain in operation in the civilian sphere, with around 50 privately owned jets registered in the US alone.

ON BOARD THE F-86E

EXPLORE THE ADVANCED ENGINEERING THAT MAKES THE SABRE SUCH A FORMIDABLE FIGHTER JET...

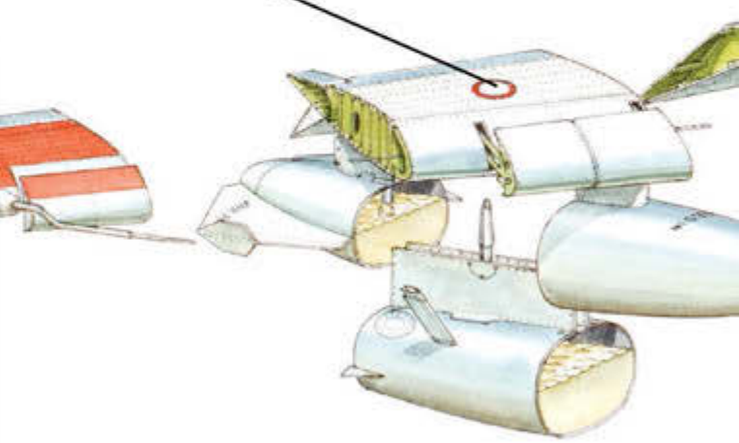
FUSELAGE

A tapered conical fuselage is installed with a nose cone air inlet. Air is ducted under the cockpit and delivered to the J47 engine before being expelled at the rear via a nozzle.



WING

Both wings and tail are swept back, with the former fitted with electrically operat ed flaps and automatic leading-edge slats. The swept wings lend it excellent agility in dogfights.



Although built in North America at least 20 other countries used Sabres in their air forces, including Japan, Spain and the UK

"THE F-86 SABRE WAS ONE OF THE FIRST MILITARY JETS CAPABLE OF FIRING GUIDED AIR-TO-AIR MISSILES"

F-86E SABRE

LENGTH 11.3M (37FT)
WINGSPAN 11.3M (37FT)
HEIGHT 4.3M (14FT)
MAX SPEED 1,046KM/H (650 MPH)
RANGE 1,611KM (1,001MI)
MAX ALTITUDE 1,371M (45,000FT)
COMBAT WEIGHT 6,350 TONS (14,000LB)

WHO WAS HIGH FLYER JACQUELINE COCHRAN?

Born in 1906, Jacqueline Cochran was a pioneering American aviator and one of the most gifted pilots of her generation. This skill in the air eventually led her to become the first woman in the world to officially break the sound barrier – a truly amazing achievement which she performed in a custom-built, one-off F-86 Sabre.

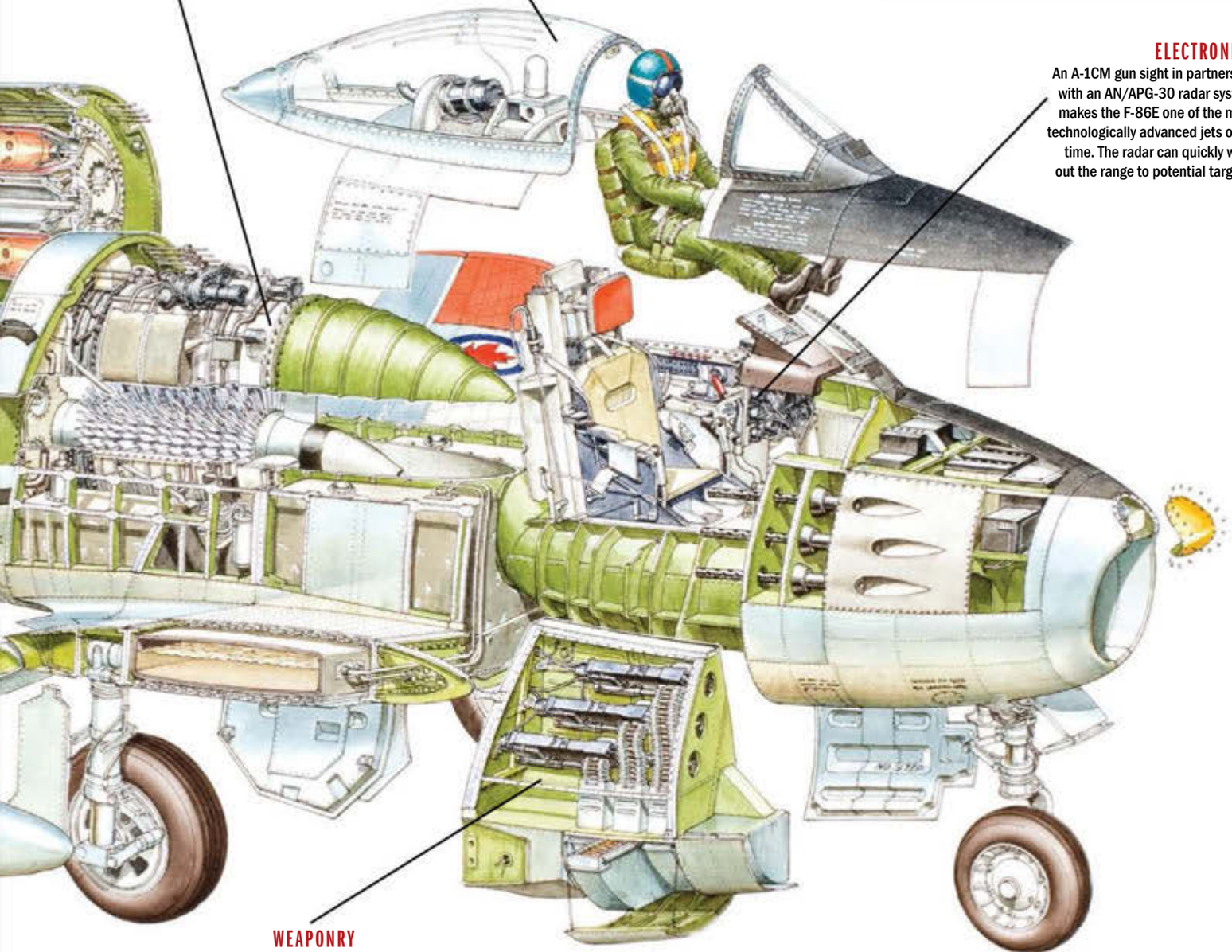
The record was broken on 18 May 1953 at Rogers Dry Lake in California. In her F-86, Cochran racked up an average speed of 1,050 kilometres (652 miles) per hour, breaking the sound barrier with fellow famous pilot Chuck Yeager as her wingman. Cochran would also go on to become the first woman to take off from an aircraft carrier as well as to reach Mach 2.

ENGINE

The F-86E uses a GE J47-13 turbojet engine capable of outputting 2,358kgf (5,200lbf) of thrust. This raw power grants it a top horizontal speed of about 1,050km/h (650mph).

COCKPIT

The F-86E is fitted with a small bubble canopy cockpit that covers a single-seat cabin. The cockpit is in a very forward position, tucked just behind the nose cone.



ELECTRONICS

An A-1CM gun sight in partnership with an AN/APG-30 radar system makes the F-86E one of the most technologically advanced jets of its time. The radar can quickly work out the range to potential targets.

WEAPONRY

The Sabre is equipped with six .50-caliber (12.7mm) M2 Browning machine guns and 16 127mm (5in) HVAR rockets, as well as a variety of freefall bombs and unguided missiles.

A Vulcan takes off at Farnborough International Airshow, England

DELTA WING

The Vulcan's revolutionary delta wing plan allowed the engines, undercarriage, fuel tanks and payload to be enclosed within a low-drag profile. This granted the Vulcan great high speed and altitude performance.

ELECTRONICS

The Vulcan's electronics included a terrain following radar (TFR), navigation and bombing system (NBS) and H2S radar with nose-mounted scanner.
A tail-mounted warning radar also helped to spot enemy aircraft and missiles.

PAYLOAD

The Vulcan could carry 21 454kg (1,000lb) conventional bombs, a gravity-guided, 4,536kg (10,000lb) nuclear bomb or a stand-off nuclear missile. A small number were also installed with Skybolt missiles.

AVRO VULCAN

The world's first delta-winged bomber, the Avro Vulcan was an aerial titan, capable of delivering a 4,536kg nuclear bomb to any hostile target within a huge radius

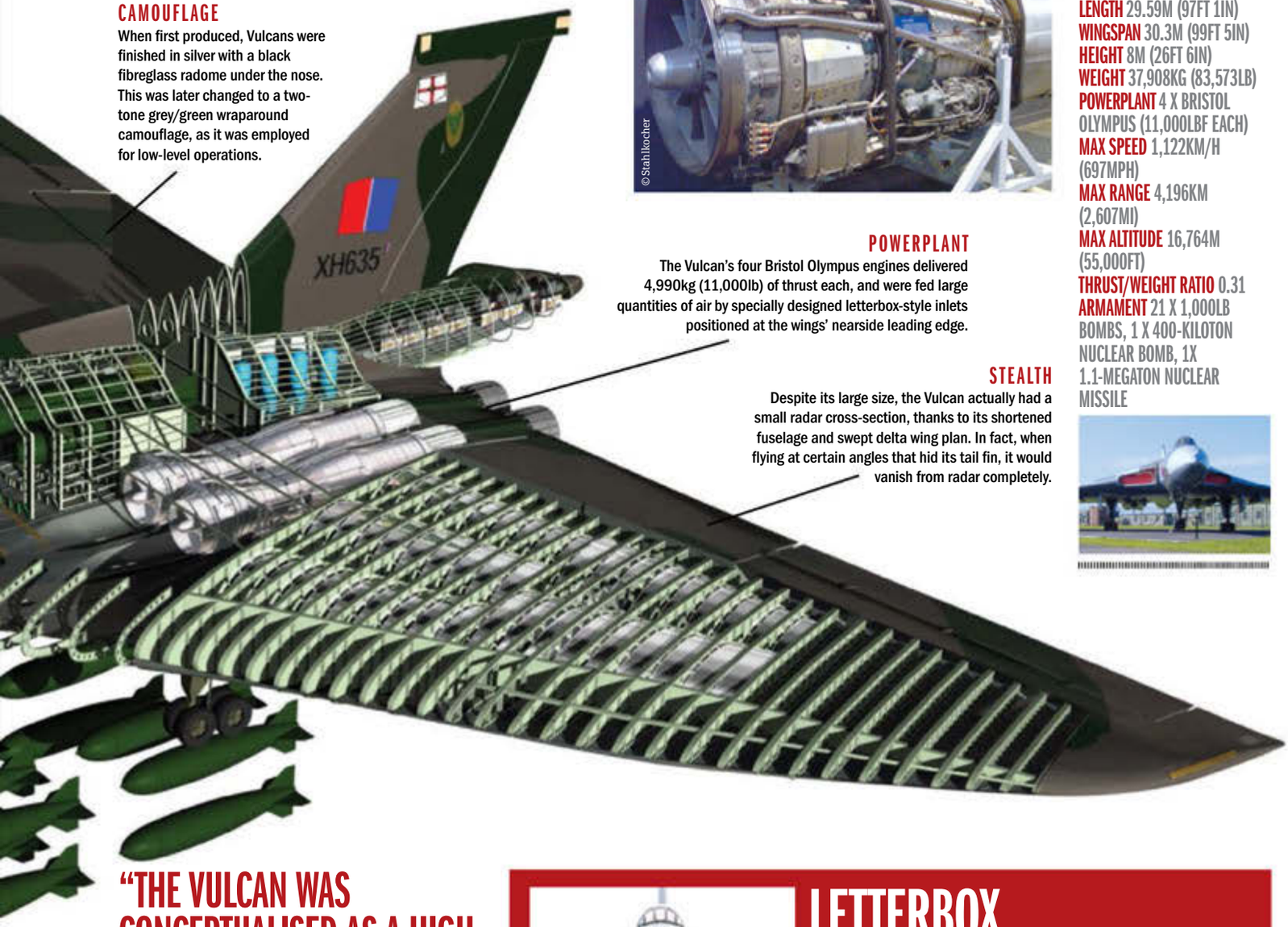
Born in the aftermath of World War II – where despite years of conventional warfare, the war was won in the east with the simple dropping of two atomic bombs on Hiroshima and Nagasaki – the Avro Vulcan was designed to be Britain's first line of atomic offence in future conflicts. A new era of modern warfare was emerging from the flames and dust that had consumed Europe, Africa, Russia, Japan and others. No longer would wars be fought and won by armies – they were to be prevented through the power of splitting the atom. The Vulcan was conceptualised as a high-altitude, high-speed, strategic bomber, capable of delivering a single 4,536kg (10,000lb) nuclear weapon to any target within a distance of 2,776km (1,725 mi). To achieve this demanding brief, the aircraft needed to feature an innovative aerodynamic structure, as conventional aircraft of the day were unsuitable. Further, as the nuclear weapon itself had yet to be invented, the aircraft would have to be developed in partnership with it, adjusting its plans accordingly.

Upon completion of the Vulcan prototype, it featured a revolutionary delta wing planform – a triangular wing layout – that granted phenomenal lift and airframe manoeuvrability. The planform also allowed the jet to fly at high subsonic and transonic speeds with ease and granted it a high angle of attack and stall angle. These features also meant that it was perfectly stable when cruising at low speeds – something normal wings on high-speed aircraft were unable to achieve safely and consistently. In addition, its sleek aerodynamic profile – despite its large size – gave the Vulcan a small radar cross-section, providing a decent level of stealth for the time.

Four colossal Bristol Olympus axial-flow turbojet engines, each capable of delivering 4,990kg (11,000lb) of thrust, powered the

ANATOMY OF THE VULCAN

CAMOUFLAGE
When first produced, Vulcans were finished in silver with a black fibreglass radome under the nose. This was later changed to a two-tone grey/green wraparound camouflage, as it was employed for low-level operations.



The Bristol Olympus axial-flow turbojet engines on the Vulcan provide 4,990kg (11,000lb) of thrust

POWERPLANT
The Vulcan's four Bristol Olympus engines delivered 4,990kg (11,000lb) of thrust each, and were fed large quantities of air by specially designed letterbox-style inlets positioned at the wings' nearside leading edge.

STEALTH
Despite its large size, the Vulcan actually had a small radar cross-section, thanks to its shortened fuselage and swept delta wing plan. In fact, when flying at certain angles that hid its tail fin, it would vanish from radar completely.

AVRO VULCAN B.1

CREW 5
LENGTH 29.59M (97FT 1IN)
WINGSPAN 30.3M (99FT 5IN)
HEIGHT 8M (26FT 6IN)
WEIGHT 37,908KG (83,573LB)
POWERPLANT 4 X BRISTOL OLYMPUS (11,000LBF EACH)
MAX SPEED 1,122KM/H (697MPH)
MAX RANGE 4,196KM (2,607MI)
MAX ALTITUDE 16,764M (55,000FT)
THRUST/WEIGHT RATIO 0.31
ARMAMENT 21 X 1,000LB BOMBS, 1 X 400-KILOTON NUCLEAR BOMB, 1X 1.1-MEGATON NUCLEAR MISSILE

"THE VULCAN WAS CONCEPTUALISED AS A HIGH-SPEED, STRATEGIC BOMBER CAPABLE OF DELIVERING A NUCLEAR WEAPON"

LETTERBOX
Thanks to the Vulcan's revolutionary delta wing planform, its four Bristol Olympus engines could be enclosed with a low drag shape close to the fuselage to maximise aerodynamic performance at speed. Engines were positioned in pairs and fed by two large letterbox-style air inlets in the wing root leading edge. This ensured that the axial flow turbojets got the right amount of air to operate, with maximum power when needed.

Vulcan. The engines were paired and buried in the delta wings close to the fuselage, and were fed with air through two large letterbox-style inlets in the wing root leading edge. The positioning of the engines and short fuselage allowed a larger space to be reserved for internal equipment and payload. At full power, the Vulcan could hit a top speed of 1,122km/h (697mph), just shy of Mach 1, and could cruise at 912km/h (567mph/Mach 0.86).

Partnering the Vulcan's revolutionary design was a comprehensive suite of avionics and electronic systems. Navigation and bombing was handled by an H2S radar with nose-mounted scanner, the first ever airborne, ground-scanning radar system. This allowed the Vulcan's crew to identify and engage targets in night or poor-weather conditions. In addition, a Red Steer tail-warning radar allowed the jet's Air Electronics Operator to quickly spot enemy fighter aircraft and launch chaff and flares accordingly to negate missile attacks. In the second edition of the aircraft, the Vulcan was also outfitted with an AC electrical system, flight refuelling probe, autopilot system and electronic counter measure (ECM) suite.

Both the Vulcan's design and advanced technology worked together in order to aid its ability to deliver munitions to enemy targets. Across its life span, the Vulcan was armed with a variety of nuclear and conventional weapons, ranging from standard free-fall bombs, through nuclear bombs and onto standoff nuclear missiles. Luckily, despite its huge arsenal, the Vulcan was never called upon to go nuclear. Instead it only saw one combat operation (Operation Black Buck) in the Falklands War, dropping conventional bombs on Port Stanley Airport, Falkland Islands.

Despite lack of actual combat missions, the Avro Vulcan is nevertheless seen as a remarkable engineering achievement. It is considered by military historians to be a piece of technology central to nuclear deterrence throughout the 20th Century.

SEA VIXEN

Sporting one of the most notable post-war aircraft designs, the de Havilland Sea Vixen was a fearsome all-weather jet fighter, capable of taking its pilots supersonic and delivering a titanic amount of next-generation firepower

The first British fighter to be fitted purely with missiles, rockets and bombs – rather than the heavy calibre machine guns relied upon in WWI and WWII – the Sea Vixen was a first generation jet fighter employed by the Fleet Air Arm of the Royal Navy. It was famed for its ability to pass the sound barrier, going supersonic when in a shallow dive (hitting a top speed of 690mph) and saw action in multiple missions in the Middle East and Africa during the Sixties and Seventies.

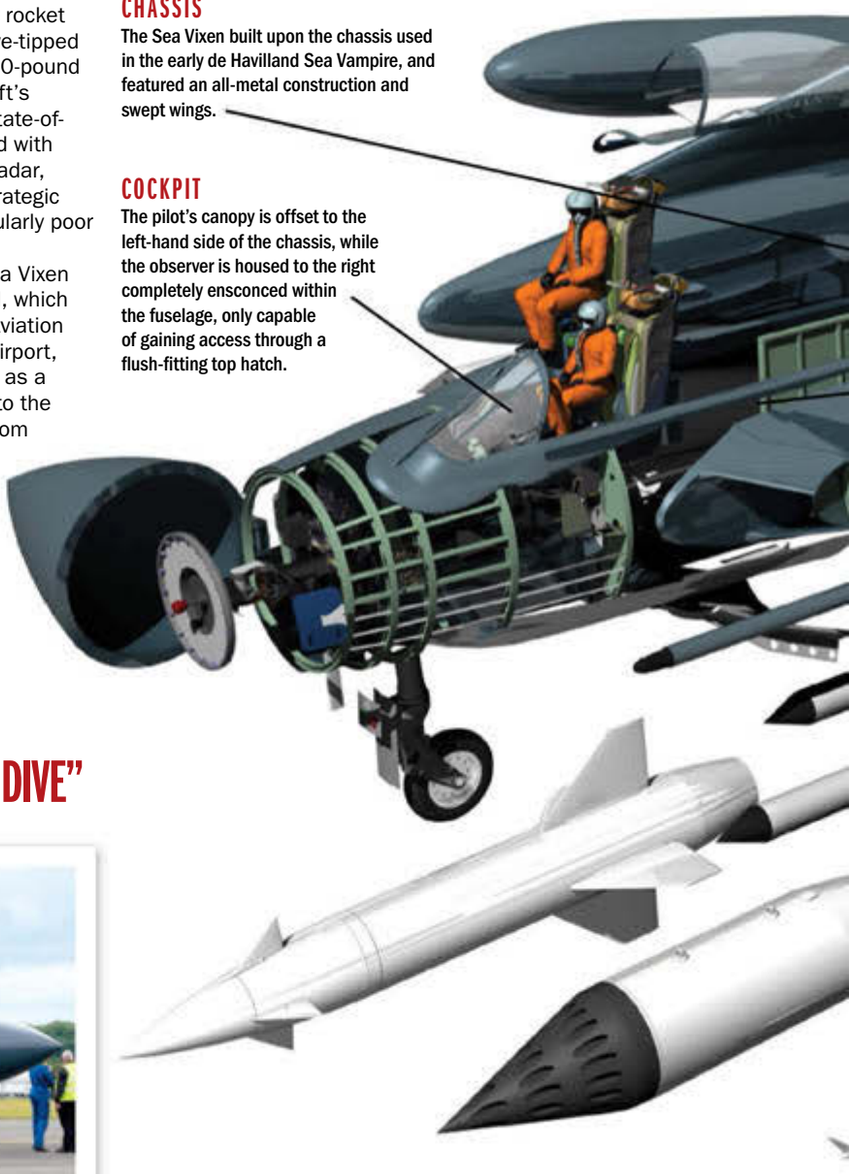
Designed to be deployed from aircraft carriers as an all-weather fighter and high-speed reconnaissance jet, the Sea Vixen worked by partnering the reinforced twin-boom tail layout as seen on its predecessors the Sea Vampire and Sea Venom, with the colossal power generated by twin Rolls-Royce Avon 208 turbojet engines, each capable of delivering 7,500lb of thrust. This gave the Vixen massive speed, a range of 600 miles – the twin-boom layout allowed for more fuel tanks – and a flexibility to engage targets at sea, on land and in the air, as well as conduct lengthy patrols.

The armament of the Sea Vixen was revolutionary for the time. With six hardpoints (areas that weapons can be mounted on) capable of being fitted with a selection of Firestreak air-to-air missiles, which sported annular blast fragmentation warheads, SNEB rocket pods with 68 unguided explosive-tipped rockets each, and whopping 500-pound air-to-ground bombs. The aircraft's detection of targets was also state-of-the-art, the Sea Vixen was fitted with the GEC AI.18 Air Interception radar, which gave the jet incredible strategic vision even at night or in particularly poor visibility conditions.

In 2010, only one working Sea Vixen now survives in the entire world, which is maintained by De Havilland Aviation at Bournemouth International Airport, Britain. After being declassified as a military aircraft and entered onto the civil register (changing its tag from XP924 to G-CVIX), the aircraft was used for a time as an advertising vehicle for Red Bull but has recently been repainted with its original Fleet Air Arm 899 NAS colours and now flies regularly as part of demonstrations and air shows across the United Kingdom.

CHASSIS
The Sea Vixen built upon the chassis used in the early de Havilland Sea Vampire, and featured an all-metal construction and swept wings.

COCKPIT
The pilot's canopy is offset to the left-hand side of the chassis, while the observer is housed to the right completely ensconced within the fuselage, only capable of gaining access through a flush-fitting top hatch.



"IT WAS FAMED FOR ITS ABILITY TO PASS THE SOUND BARRIER, GOING SUPERSONIC WHEN IN A SHALLOW DIVE"

The Red Bull plane repainted in its original livery

The Sea Vixen could reach speeds of up to 690mph

SEA VIXEN

CREW 2
LENGTH 16.9M
WINGSPAN 15.5M
EMPTY WEIGHT 12,680KG
LOADED WEIGHT 18,860KG
POWERPLANT 2 X ROLLS-ROYCE AVON MK.208 TURBOJETS
MAX SPEED 690MPH
RANGE 790MI
SERVICE CEILING 14,630M
ARMAMENT 4 X MATRA ROCKET PODS WITH 18 SNEB 68MM ROCKETS EACH, 4 X RED TOP AIR-TO-AIR MISSILES, 2 X 227KG BOMBS

©Tony Hisgett

TWIN-BOOM

Another similarity shared with the Sea Vampire was the Sea Vixen's twin boom tail layout, which aided strength and rigidity when travelling at sub-sonic and near sub-sonic speeds.

©Alex Pang

POWERPLANT

It was powered by two Rolls-Royce Avon 208 turbojet engines, each capable of producing 7,500 pounds of thrust. This massive power allowed the jet to go supersonic in a shallow dive.

ARMAMENT

The Vixen had six hardpoints upon which it could carry a combination of Matra rocket pods with 18 SNEB 68mm rockets each, Firestreak air-to-air missiles and 227kg high-explosive bombs.

A Sea Vixen with Red Bull advertising

F-4 PHANTOM II

One of the most iconic fighter planes ever, the F-4 Phantom II set 15 world records during its lifetime

The F-4 was one of the most technologically advanced fighter-interceptors of its generation. Breaking numerous records – highest-altitude flight, fastest flight speed and fastest zoom climb to name but a few – and introducing advanced new construction materials and aviation features, the jet ruled the skies from 1960 up until the end of the Seventies.

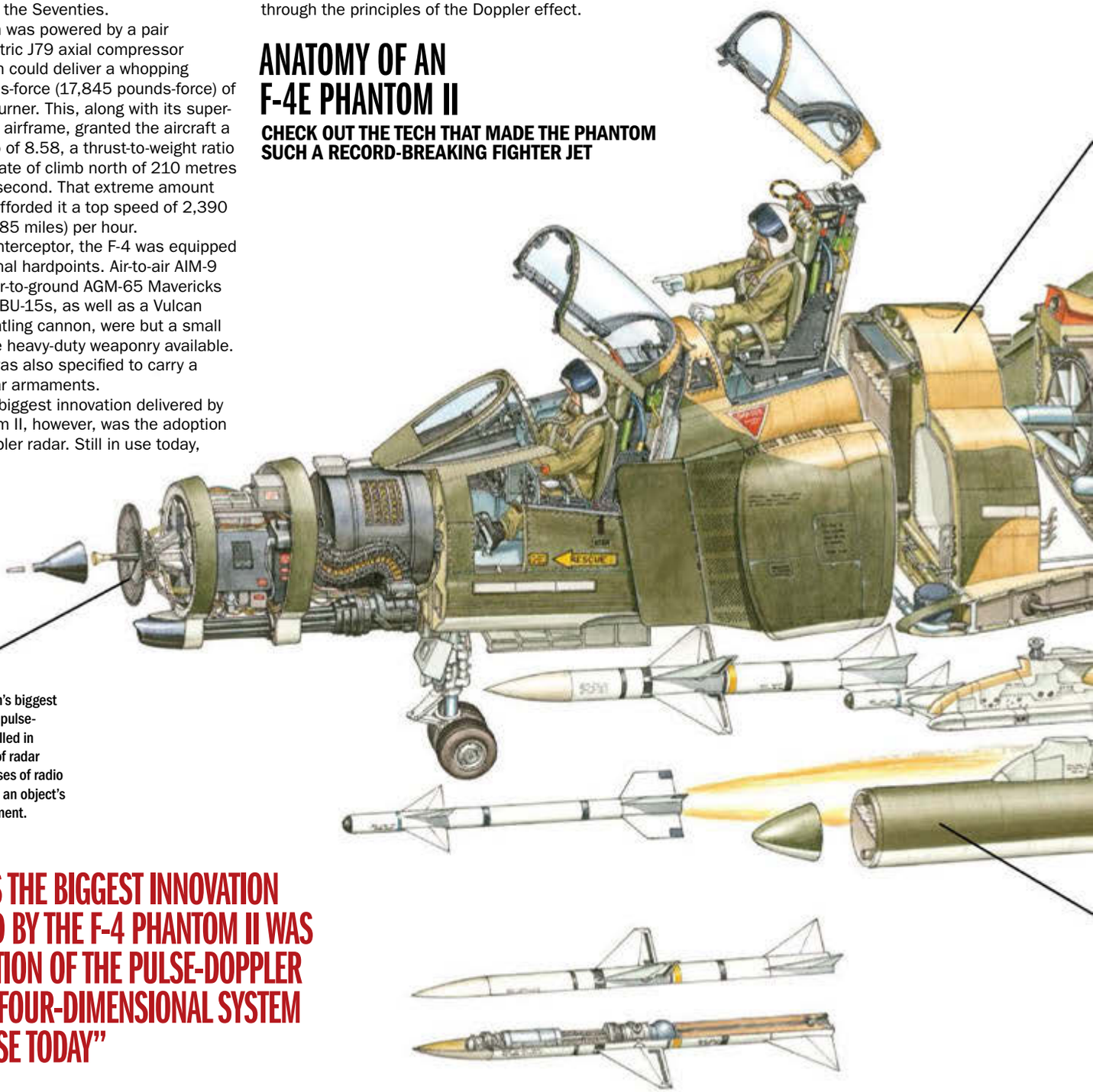
The Phantom was powered by a pair of General Electric J79 axial compressor turbojets, which could deliver a whopping 8,094 kilograms-force (17,845 pounds-force) of thrust in afterburner. This, along with its super-strong titanium airframe, granted the aircraft a lift-to-drag ratio of 8.58, a thrust-to-weight ratio of 0.86 and a rate of climb north of 210 metres (689 feet) per second. That extreme amount of power also afforded it a top speed of 2,390 kilometres (1,485 miles) per hour.

As a fighter-interceptor, the F-4 was equipped with nine external hardpoints. Air-to-air AIM-9 Sidewinders, air-to-ground AGM-65 Mavericks and anti-ship GBU-15s, as well as a Vulcan six-barrelled Gatling cannon, were but a small selection of the heavy-duty weaponry available. In addition, it was also specified to carry a range of nuclear armaments.

Perhaps the biggest innovation delivered by the F-4 Phantom II, however, was the adoption of a pulse-Doppler radar. Still in use today, this is a four-dimensional radar system that's capable of detecting a target's 3D position and its radial velocity. It does this by transmitting short bursts of radio waves (rather than a continuous wave), which after being partially bounced back by the airborne object, are received and decoded by a signal processor, which discerns its location and flight path through the principles of the Doppler effect.

ANATOMY OF AN F-4E PHANTOM II

CHECK OUT THE TECH THAT MADE THE PHANTOM SUCH A RECORD-BREAKING FIGHTER JET



RADAR

One of the Phantom's biggest innovations was its pulse-Doppler radar installed in its nose. This type of radar transmits short pulses of radio waves to determine an object's position and movement.

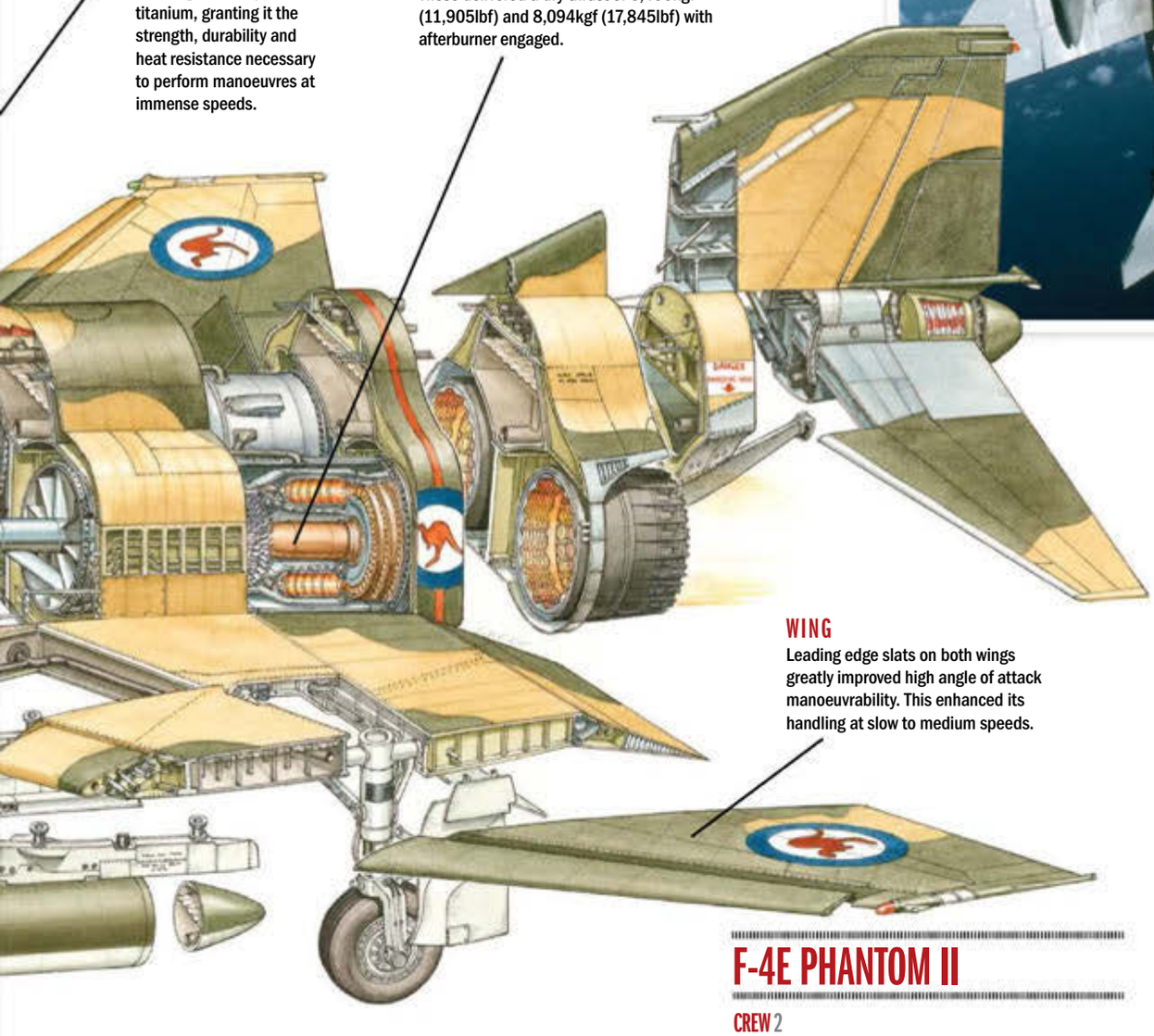
"PERHAPS THE BIGGEST INNOVATION DELIVERED BY THE F-4 PHANTOM II WAS THE ADOPTION OF THE PULSE-DOPPLER RADAR, A FOUR-DIMENSIONAL SYSTEM STILL IN USE TODAY"

A South Korean F-4E patrols the skies, armed with an AGM-65 Maverick missile

Nine external hardpoints could be installed offering an arsenal of heavy firing power

AIRFRAME
The Phantom's airframe was forged heavily from titanium, granting it the strength, durability and heat resistance necessary to perform manoeuvres at immense speeds.

POWERPLANT
The F-4E was equipped with two GE J79-GE-17A axial compressor turbojets. These delivered a dry thrust of 5,400kgf (11,905lbf) and 8,094kgf (17,845lbf) with afterburner engaged.



WING
Leading edge slats on both wings greatly improved high angle of attack manoeuvrability. This enhanced its handling at slow to medium speeds.

ARMAMENTS
Up to 8,480kg (18,650lb) of weapons on nine hardpoints could be carried. These included laser-guided bombs, rocket pods and heat-seeking missiles.

F-4E PHANTOM II

CREW 2
LENGTH 19.2M (63FT)
WINGSPAN 11.7M (38FT)
HEIGHT 5M (16.4FT)
POWERPLANT 2X GENERAL ELECTRIC J79-GE-17A TURBOJETS
MAX THRUST 8,094KGF (17,845LBF)
MAX SPEED 2,390KM/H (1,485MPH)
MAX ALTITUDE 18,300M (60,000FT)

5 Facts about F-4 PHANTOM II

SPOOKY
The Phantom's emblem was a whimsical cartoon ghost referred to as 'The Spook' by pilots. It was designed by McDonnell Douglas technical artist Anthony Wong.

NICKNAMES
The Phantom acquired a number of nicknames during its long career including the Rhino, Flying Anvil, Flying Footlocker, Lead Sled and the St Louis Slugger.

EXPORT
The Phantom was not only used in North America but also in many other national militaries around the world, being exported to Greece, Germany and Iran to name just a few countries.

ANGELS
The F-4J Phantom II variant also saw plenty of non-military action. For instance, it was flown by the US aerobatic display team, the Blue Angels, from 1969 through to 1974.

OBSOLETE
The F-4 Phantom II was eventually superseded by a brace of newer fighter jets manufactured from the Eighties onwards. These included F-14 Tomcats and F/A-18 Hornets.

WESTLAND WASP

The first of a new breed of anti-submarine helicopters, the Westland Wasp was small but deadly

Submarines have the ability to strike fear into entire navies, so several countermeasures have been designed to combat their destructive capabilities. These include anti-submarine helicopters such as the Westland Wasp, which was heavily involved in the Falklands War. With good range and speed, the Wasp was a useful all-rounder in the Royal Navy's fleet and could land on both large battleships, such as the HMS Bristol and HMS Endurance, and small Leander- and Rothesay-class frigates. When an enemy sub was sighted, Wasps would quickly be dispatched to eliminate the threat.

During the 1982 war, the Argentinian submarine Santa Fe was a hazard to the British fleet as it attempted to land on the South Georgia Islands. On 25 April, along with the larger Westland Lynx and Westland Wessex, a Wasp struck the Santa Fe with AS-12 air-to-surface missiles. The submarine wasn't sunk, but was too damaged to manoeuvre or submerge to safety. It was boarded and disabled, taking it out of the war. The Wasp was the first of a new breed of helicopter that used gas-turbine generators and set the bar for the future of anti-submarine helicopters. 96 of the machines were built for the Royal Navy before being replaced by the Westland Lynx in 1988. Wasps continued to serve other navies across the globe such as Brazil, Indonesia, Malaysia, Netherlands, New Zealand and South Africa until 2000 when the model was finally discontinued.

A pair of Westland Wasp helicopters from 829 Naval Air Squadron in flight July 1984

WESTLAND WASP HAS.1

COMMISSIONED 1965
ORIGIN Fairey Factory, Hayes, Middlesex, UK
LENGTH 12.3m (40ft)
ENGINE Rolls-Royce Nimbus 103 Turboshaft
TOP SPEED 222km/h (138mph)
CREW 2-5
WEAPONS Two MK 44/MK 46 torpedoes, AS.11/AS/12 missiles, machine gun

The first Westland Wasp prototype was showcased at the Farnborough Air Show on 8 September 1962 and they are still used in displays to this day

The cabin was made from a tough aluminium alloy structure to protect the crew from the elements when in flight. The cockpit included an device on the roof to help missiles hit their designated target

"WHEN AN ENEMY SUB WAS SIGHTED, WASPS WOULD BE QUICKLY DISPATCHED TO ELIMINATE THE THREAT"

Dials illustrated all of the helicopter's levels including fuel and speed. At 222km/h (138mph), the agile Wasp could strafe surfaced submarines with its machine gun

A Wasp was controlled by a cyclic stick, which is common in many similar sized craft and gives the pilot complete control

The cabin was big enough for five people: a pilot, an aircrewman and three soldiers if required

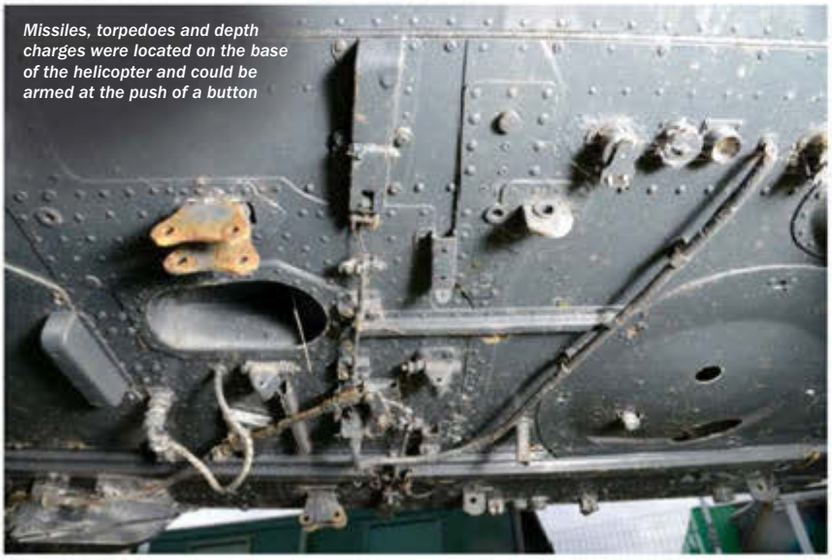
INTERIOR AND COCKPIT

The cockpit was the control centre of the Wasp and powered everything from flight to communications to armaments. The pilot would sit on the right and would be supported by an aircrewman who would help with navigation, the weapon systems and the general execution of the mission in hand. In larger and more-modern helicopters, he would often be assisted by an observer to help navigate. Up to three extra people would occasionally sit in the rear, but a stretcher often took the space for rescue missions. If the pilot had to make an emergency landing, the Wasp was fully kitted out with inflatable flotation gear, in case the ocean was the only option available.

Unlike the similar Westland Scout, the Wasp had quadricycle landing gear for landing on smaller vessels

***Below:** As well as weapons, the craft also contained flares and cables that could be used to winch up stranded personnel*

"IF THE PILOT HAD TO MAKE AN EMERGENCY LANDING THE WASP WAS FULLY KITTED OUT WITH INFLATABLE FLOATATION GEAR"



Missiles, torpedoes and depth charges were located on the base of the helicopter and could be armed at the push of a button

HELICOPTERS OF THE FALKLANDS

AS WELL AS THE WASP, VARIOUS OTHER MODELS OF HELICOPTER WERE SENT ON THE 12,789-KILOMETRE (7,947-MILE) JOURNEY TO THE FALKLANDS. HERE'S A RUNDOWN OF THE MAJOR TYPES:

WESTLAND LYNX

***Role:** Multi-purpose, patrol and anti-submarine warfare*

WESTLAND WESSEX

***Role:** Logistics, search and rescue*

WESTLAND SEA KING

***Role:** Anti-submarine, troop transport*

The Wasp engines were originally manufactured by aerospace engineering company Bristol Siddeley before its takeover by Rolls-Royce

ENGINE POWER

The engine of choice for the Wasp was the Nimbus 103 Turboshaft produced by British company Rolls-Royce. Its power could reach 710 shp (shaft horsepower), but would be restricted by the amount of people in the cabin and the total armament carried. The Nimbus engine incorporated a new turboshaft design, which was ideally suited to the Wasp with its low weight-to-power ratio. Gas-turbine generators, like the one used in the Wasp, would transform the small helicopter's role in warfare, enabling it to carry more armament and be of generally more use on the battlefield.

ARA SANTA FE

One of two submarines used by the Argentineans during the war (the other being the ARA San Luis), the ARA Santa Fe was originally an American vessel before it was purchased by the Argentinean Navy in 1971. It was a constant thorn in the side of the Royal Navy ferrying troops across the Falklands. Although she never engaged a British ship, her sheer presence ensured the British forces maintained their distance. The threat was ended by an AS-12 missile delivered from a Wasp on 25 April 1982, after the submarine was spotted off the coast of King Edward Point, South Georgia. Although not destroyed, the Santa Fe was disabled and scuttled by the British shortly after.

Engine failure wasn't common in Westland Wasps but that wasn't the case for the Wasp of the HMS Cleopatra, which activated its flotation device after this unfortunate incident

THE BOURNEMOUTH AVIATION MUSEUM

On August 1999, the Bournemouth Aviation Museum was established on the same site as Bournemouth Airport. Originally part of the now defunct Jet Heritage Museum, the centre strives to be a hands-on experience. It houses 15 aircraft ranging from military jets to a Boeing 737. Visitors are encouraged to jump in the cockpit and have a go in a truly interactive experience.
www.aviation-museum.co.uk

The Wasp's engine was powerful enough to withstand the weight of torpedoes, missiles and depth charges, and enabled the Wasp a maximum take-off weight of 2,500kg (5,512lbs)

"GAS-TURBINE GENERATORS WOULD TRANSFORM THE SMALL HELICOPTER'S ROLE IN WARFARE"

SYSTEMS AND ELECTRONICS

The Wasp had a very complex network of features for a craft of its size. Autopilot and autostabilisation capabilities, as well as a hydraulic system, made life much easier for the pilot and made it ideal for use as a training helicopter. A 28-Volt electrical supply powered an intercom and radio that enabled the Wasp to be in constant contact with base for attack, reconnaissance and rescue missions.

WEAPONS USED TO DISABLE THE ARGENTINIAN SUBMARINE

MK46 TORPEDOES

Specifically designed for tackling submarines, a MK46 was launched at the Santa Fe by a Westland Lynx helicopter, but didn't register a hit. If it had done, the submarine would have recorded more-significant damage and may have sunk.

AIR-TO-SURFACE MISSILES

The Wasp was originally armed with SS.11 missiles, but these were later upgraded to AS-12 anti-ship missiles. All three Wasps that attacked the Santa Fe made critical hits.

MACHINE GUNS

Before the attack began, the Santa Fe was forced to surface after an initial assault from HMS Antrim so depth charges were not useable. Instead, the submarine was sprayed with machine gun fire.

A-10 THUNDERBOLT II

Why is the A-10 Thunderbolt fighter jet still in use today and just as popular as it was four decades ago when it first took off?

The A-10 Thunderbolt is a single-seat, close-air support fighter jet that also goes by the names Warthog and Tankbuster. Development for the aircraft began in 1967 and its first flight was in 1972. There are several reasons why the A-10 has proved popular enough to weather 40-plus years of advancing military tech – chief among them its combat versatility and high survival rate.

The A-10 boasts a short takeoff and landing capacity with a range of nearly 1,300 kilometres (800 miles). Commonly used for troop support and ground attacks, it can loiter for long periods at low speeds and altitudes below 300 metres (985 feet) and it's capable of soaking up as much damage as it can dish out. Indeed, the A-10 can take direct hits from armour-piercing and explosive shells, has multiple redundancies for its flight systems and, most incredibly, it can return to base on one engine, one tail stabiliser, one elevator and even having lost half a wing! As a result, it's well known among US Air Force pilots for its 'get home' effectiveness.

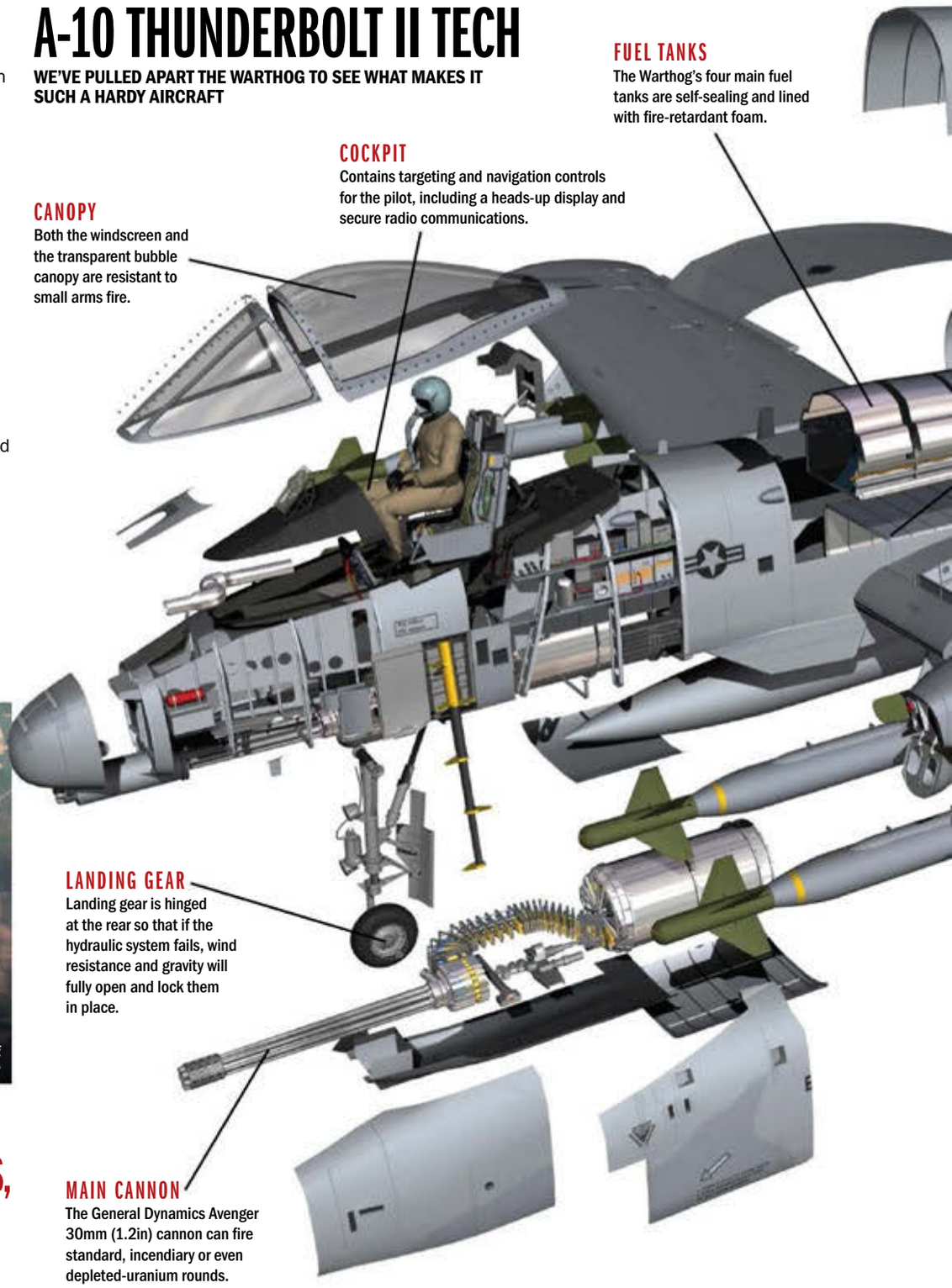
Modern A-10s have been upgraded from the original 1972 blueprint, of course. Navigation and targeting systems have been dramatically improved. Pilots can now wear night-vision goggles for low-light ops, plus a host of electronic countermeasures and smart-bomb capacity have been installed.

An A-10A cruising during Operation Allied Force

"COMMONLY USED FOR TROOP SUPPORT AND GROUND ATTACKS, IT CAN LOITER FOR LONG PERIODS AT LOW ALTITUDES"

A-10 THUNDERBOLT II TECH

WE'VE PULLED APART THE WARTHOG TO SEE WHAT MAKES IT SUCH A HARDY AIRCRAFT



FUEL TANKS

The Warthog's four main fuel tanks are self-sealing and lined with fire-retardant foam.

COCKPIT

Contains targeting and navigation controls for the pilot, including a heads-up display and secure radio communications.

CANOPY

Both the windscreen and the transparent bubble canopy are resistant to small arms fire.

LANDING GEAR

Landing gear is hinged at the rear so that if the hydraulic system fails, wind resistance and gravity will fully open and lock them in place.

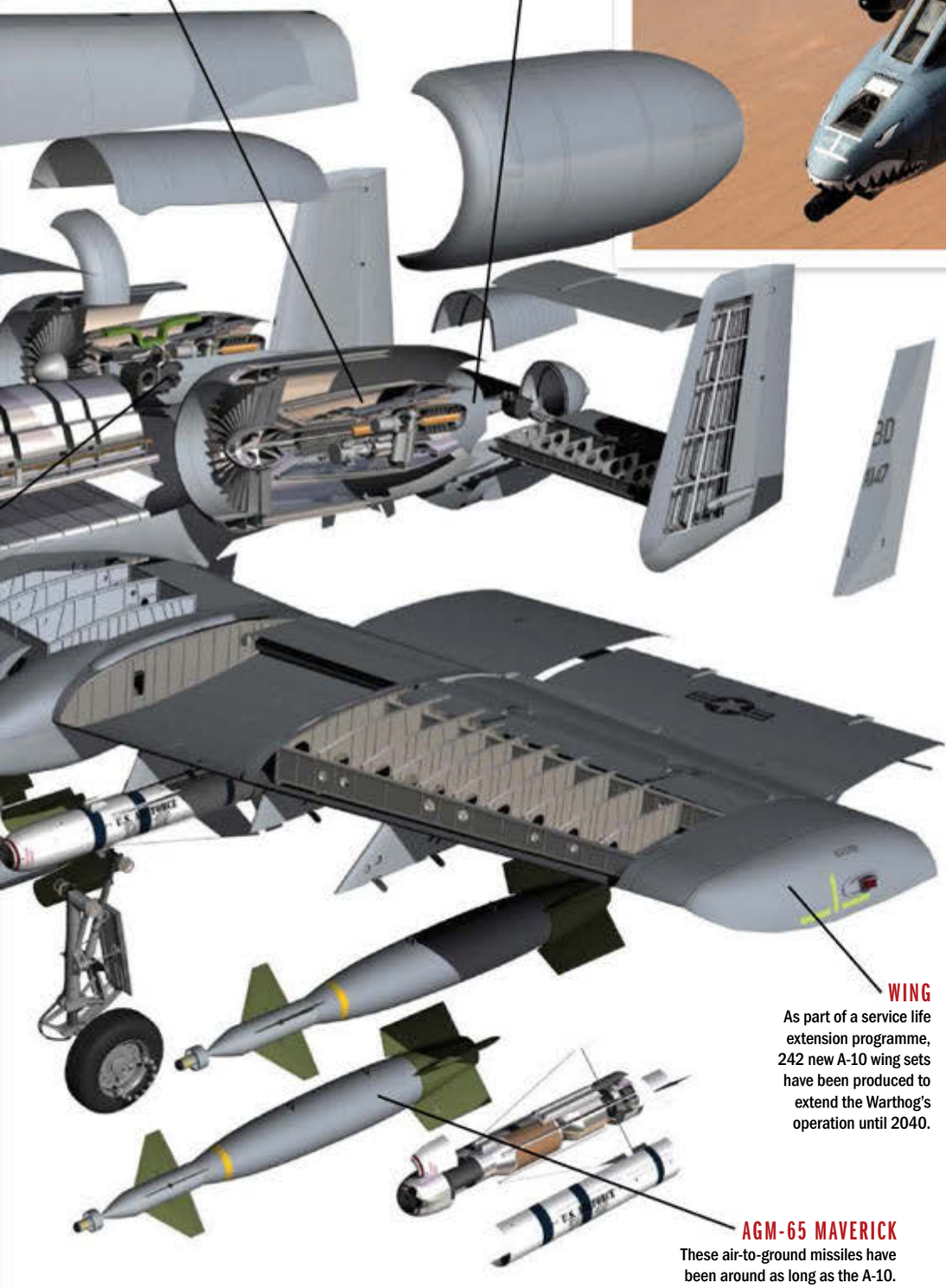
MAIN CANNON

The General Dynamics Avenger 30mm (1.2in) cannon can fire standard, incendiary or even depleted-uranium rounds.

The US Air Force boasts over 360 A-10s in its fleet, operating all around the world, including this one in Afghanistan

ENGINES
Two TF34-GE-100, non-afterburning, twin turbofans provide 4,111kg (9,065lb) of thrust each.

TAIL
The engines are mounted here to reduce heat signature (for evading heat-seeking missiles) and to enable the plane to fly on just one engine.



WING
As part of a service life extension programme, 242 new A-10 wing sets have been produced to extend the Warthog's operation until 2040.

AGM-65 MAVERICK
These air-to-ground missiles have been around as long as the A-10. They're equipped with either contact or delayed-action fuses.

BUILT FOR DEFENCE

The A-10 is robust enough to sustain heavy damage during combat and remain capable of flying away, where other aircraft would be compromised. It's exceptionally well-armoured around the cockpit, where the pilot is vulnerable. Sensitive parts of the flight control system, along with the pilot, are shielded by a 'tub' of titanium armour: 544 kilograms (1,200 pounds) of this super-hard metal is layered in plates up to 3.8 centimetres (1.5 inches) thick around the cockpit, based on the likely trajectories of incoming projectiles. It can withstand fire from similar cannons to its own main weapon, as well as large-calibre rounds. A nylon spall shield also protects the pilot from shrapnel and round fragmentation, while the transparent canopy (which can't afford the same level of protection) can still resist ballistics from small arms.

ON THE OFFENSIVE

The A-10 can carry nearly half its weight again in armaments and their associated systems, with an external load of up to 7,260 kilograms (16,005 pounds). It's equipped with 11 pylons along which laser weapon guidance and support systems can be attached, plus ordnance. It's capable of carrying a range of cluster and 227-kilogram (500-pound) general-purpose bombs, Hydra rockets, plus up to ten Maverick air-to-ground missiles weighing 304 kilograms (670 pounds) apiece. The latter can destroy a tank in a single hit – however, at a cost of up to £105,000 ($160,000) a pop, a cavalier attitude with the Mavericks is not tolerated. The main weapon is the Avenger 30-millimetre (1.2-inch) cannon mounted under the nose of the A-10, with a top fire rate of 4,200 rounds a minute and an effective range of over 6.5 kilometres (four miles). The cannon can easily disable a main battle tank in the hands of a competent pilot.

C-130 HERCULES

One of the longest-lasting and most widespread military transport vehicles of all time, the C-130 Hercules remains to this day an aerial behemoth, capable of flying thousands of miles to deploy troops and vehicles alike

The C-130 Hercules is a military transport aircraft famed for its durability and versatility, having been in active service for over 50 years. Since its introduction in December 1957, over 40 models and variants of the Hercules have been produced and are used today by more than 60 nations worldwide.

The aircraft works by delivering a cavernous central fuselage in which the vast cargo bay can carry a plethora of civilians, soldiers, vehicles, equipment, weapons and supplies over huge distances. This makes the Hercules an ideal tool to aid military operations in the 21st-century battlefield, where mission parameters often need to adapt fluidly and at high speed.

Indeed, the sheer lifting power of the C-130 cannot be overstated, with a single plane capable of lifting northwards of 33,000 kilograms (72,753 pounds). To put that in context, that is an ability to lift the equivalent of seven fully grown African elephants or 44 Mini Metros! As a heavy-lifting workhorse, the C-130 has few competitors capable of matching it and, as such, has seen off several contenders that were supposed to replace it (such as the C-5 Galaxy) and even spawned a larger but rarer Super Hercules variant.

All that lift comes courtesy of four Allison T56 turboprop jet engines, each capable of generating 3,423 kilowatts (4,590 shaft horsepower). The combined output makes this plane more powerful than 15 Bugatti Veyron Super Sports – the most powerful car on the planet. It also means the Hercules can not just lift more than 33,000 kilograms (72,753 pounds), but it can do so at both high altitude (the C-130 has a service ceiling of 10,000 metres (33,000 feet) and at high speed, with a cruise speed of 541 kilometres (336 miles) per hour. In addition, the titanic turboprops allow the Hercules to climb at a rate of 9.3 metres (31 feet) per second, a fact that allows it to quickly get airborne and out of range of many anti-aircraft armaments.

Interestingly, despite the US Air Force aiming to instigate a programme to produce a replacement for the C-130 in 2014 – for eventual delivery in 2024 – uptake for the programme has not been marked. Further, in December 2011, Lockheed Martin – the manufacturerof the Hercules – announced two new variants of the Hercules: the C-130XJ and C-130NG. As such, despite the aircraft being 57 years old, it is unlikely that it will be retiring in the next decade at least.

ANATOMY OF A C-130 HERCULES

WE BREAK DOWN A POPULAR VARIANT OF THIS AERIAL TITAN

AVIONICS

Later models in the H series of C-130s are installed with ring laser gyros, GPS receivers, an upgraded APN-241 colour weather and navigational radar, improved generator control and bus switching units as well as an integrated radar and missile warning system.

CREW

Due to its tremendous size and flexible capabilities, the C-130H is manned by five crew members. There are two pilots, a navigator, flight engineer and loadmaster. Due to its large carrying capacity, the loadmaster's role is to determine how to most efficiently load huge and diverse cargo.

The C-130 is one of a prestigious group of only six aircraft to have been in continuous service for over 50 years

"THE HERCULES IS AN IDEAL TOOL TO AID MILITARY OPERATIONS IN THE FAST-CHANGING CONTEMPORARY BATTLEFIELD "

POWERPLANT

Due to its immense weight, four Allison T56-A-15 turboprop engines are equipped to each C-130H. These produce a colossal 3,423kW (4,590shp) each and allow the aircraft to reach a respectable top speed of 592km/h (366mph). The T56 is a single-shaft turboprop with a 14-stage axial flow compressor.

CAPACITY

With a max takeoff weight of over 70,000kg (150,000lb), the C-130H can carry up to 92 passengers, 64 airborne troops, three Humvees or two M113 armoured personnel carriers. If specced out for a medical role, a single aircraft can carry 74 litter patients plus two medics.

GLOBAL DISTRIBUTION

The C-130's awesome versatility has seen it adopted the world over

BLUE CURRENT OPERATORS
GREEN FORMER OPERATORS

Engineers work on the turboprop engines of a Hercules deployed in Iraq

HERCULES C-130

CREW 5
HEIGHT 11.6M (38FT 3IN)
WINGSPAN 40.4M (132FT 7IN)
LENGTH 29.8M (97FT 9IN)
CAPACITY 92 PASSENGERS; 64 AIRBORNE TROOPS; 3 X HUMVEE; 2 X M113 TROOP CARRIERS
PAYLOAD 20,000KG (45,000LB)
POWERPLANT 4 X ALLISON T56-A-15 TURBOPROP (3,423KW/4,590SHP EACH)
MAX SPEED 592KM/H (366MPH)
MAX RANGE 3,800KM (2,360MI)
MAX ALTITUDE 10,060M (33,000FT)

SEPECAT JAGUAR

Climb inside the supersonic ground-attack aircraft that served air forces from all over the world for nearly 40 years

A twin-engine, single-seat jet aircraft, the Jaguar was a joint British and French project to create a supersonic strike fighter/bomber. Developed by SEPECAT, a union of Breguet Aviation and the British Aircraft Corporation, it was the first combined effort to create a combat aircraft by two major European powers. After its first flight on 23 March 1969, 588 were made. It proved immensely popular for other air forces, with the Indian Air Force (IAF) buying 40 in 1978 in a $1 billion (£664 million) deal. Their lead was followed by the air forces of Ecuador, Oman and Nigeria, who also bought models to bolster their air forces.

There have been many variants of the Jaguar since its inception. The Jaguar A was the first of the breed but it was followed by new and improved versions such as the M, which was a navy version with unique landing gear and a reinforced airframe.

The Jaguar initially had a limited attack capability but this was soon changed to more advanced roles such as reconnaissance and even tactical nuclear strikes. The jet was devised to replace the rapidly ageing McDonnell Douglas Phantom FGR2 and remained in service for a long period – it was only retired by the French Air Force in 2005 and by the RAF in April 2007. The Jaguar remains effective in modern air combat and is still in use in the IAF. Its combat history is impressive, with the Jaguar having served across the globe in the Gulf War, Balkan Wars, Kosovo War, Kargil War and Cenepa War.

The SEPECAT Jaguar made its first flight in 1969 and was so popular that it is still used by the Indian Air Force today

"THE JAGUAR INITIALLY HAD A LIMITED ATTACK CAPABILITY. THIS WAS SOON CHANGED TO MORE ADVANCED ROLES SUCH AS RECONNAISSANCE, ATTACK AND EVEN TACTICAL NUCLEAR STRIKES"

SEPECAT Jaguars flying in formation on 29 March 1974

SEPECAT JAGUAR GR1 XX763

MAIDEN FLIGHT 1975
ORIGIN UK/FRANCE
LENGTH 16.84M (55.3FT)
WINGSPAN 8.69M (28.6FT)
RANGE 535KM (335 MILES)
ENGINE 2 X ROLLS ROYCE TURBOMECA ADOUR MK 104
SPEED 1,593KM/H (1,055MPH)
CREW 1
PRIMARY WEAPON ANTI-RADAR AIR-TO-SURFACE MISSILES, AIR-TO-AIR ROCKETS, GUIDED BOMBS
SECONDARY WEAPON 2 X 30MM ADEN CANNON

The Jaguar could really pack a punch, with weaponry from Matra AS37 anti-radar missiles to AIM-9 Sidewinders

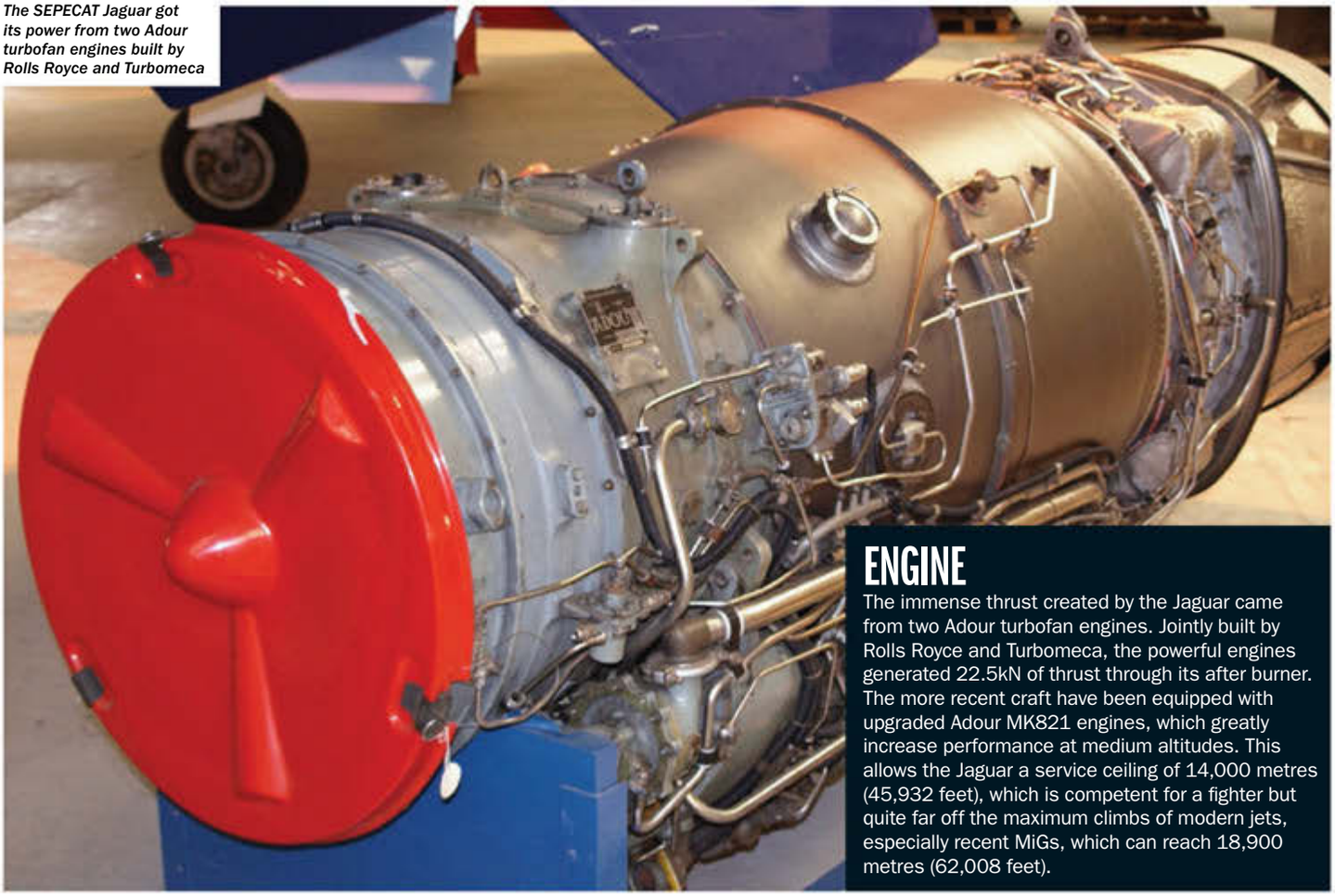
WEAPONS

The Jaguar was a force to be reckoned with in combat. Fitted with two rapid-fire 30mm DEFA cannons, the fighter-bomber could strafe and damage ground targets even before it unloaded its missiles. With 4,500-kilogram (9,921 pounds) worth of payload available to the pilot, a variety of armaments can be carried. The Jaguar's speciality was in anti-radar. Most models were equipped with laser-guided Martel missiles and Rockeye cluster bombs to take out ground targets while Sidewinders took care of anything else in the air. Finally, the Jaguar also had the capacity to carry an AN-52 nuclear warhead, representing the trust placed in the machine by its operators.

Missiles and rockets would be released from the side of the aircraft and it could only be seconds until a vehicle or building was laid to waste

Most SEPECAT Jaguar models were armed with laser-guided missiles

The SEPECAT Jaguar got its power from two Adour turbofan engines built by Rolls Royce and Turbomeca



ENGINE

The immense thrust created by the Jaguar came from two Adour turbofan engines. Jointly built by Rolls Royce and Turbomeca, the powerful engines generated 22.5kN of thrust through its after burner. The more recent craft have been equipped with upgraded Adour MK821 engines, which greatly increase performance at medium altitudes. This allows the Jaguar a service ceiling of 14,000 metres (45,932 feet), which is competent for a fighter but quite far off the maximum climbs of modern jets, especially recent MiGs, which can reach 18,900 metres (62,008 feet).

COCKPIT

The control centre of the aircraft, the cockpit of a Jaguar utilised cutting-edge technology for the time. The all-digital cockpit included multi-functional displays with built-in night vision and GPS. This was accompanied by a helmet-mounted display, radar altimeters, navigation systems, automatic direction finder, a weapon-aiming computer and information that helped the pilot distinguish friend from foe. The Navigation And Weapon-Aiming Sub System even allowed the Jaguar to attack enemies without the use of radar.

The cockpit of a Jaguar contains state-of-the-art technology that strengthens its role as a modern fighter

20TH-CENTURY SUPERSONIC FIGHTERS

WHAT WERE THE JAGUAR'S RIVALS FOR AIR SUPERIORITY?

MIG-25

Known as the Foxbat, the MiG-25 is just one in a long line of Mikoyan-Guervich fighters. Immensely powerful, the Foxbat could reach Mach 2.8 but was let down by its thirsty fuel tank. It was primarily a reconnaissance aircraft used to spy on US activity, but could also unleash missiles, as it did in the Iran-Iraq War.

F-15 EAGLE

The F-15 was so advanced for its time that it is still in use today. Boasting a max speed of twice the speed of sound, it can also hold a huge payload of armaments. It was the premier fighter for the US in the Gulf War, outclassing its rivals in Operation Desert Storm.

HARRIER JUMP JET

Still the most famous vertical take-off aircraft, the Harrier began life in the RAF in 1969. Its most famous incarnation is the Sea Harrier, which fought with distinction in the Falklands War. The design was ported across Europe to Spain and Italy and it remains in service around the world.

"THE PLANE'S SYSTEMS COME COMPLETE WITH SPOILERS, AIR BRAKES AND A BULLETPROOF WINDSCREEN"

DESIGN

Constructed with an aluminium airframe, the Jaguar can handle extreme weather conditions and speeds of up to 1,593 kilometres per hour (1,055 miles per hour). It is equipped with an in-flight refuelling probe that allows the aircraft to be refuelled mid-air. The plane's systems come complete with spoilers, air brakes and a bulletproof windscreen. In later models of the Jaguar, Ferranti laser rangers and marked-target seekers were added to the nose as part of even more advanced armaments. The aircraft is covered in an all-over wrap-round camouflage that helps the Jaguar avoid detection.

The landing gear's low-pressure tyres retract into the fuselage on takeoff. The IAF initially reported failures, which then led to the system being upgraded

The aerodynamic and streamlined design allows the Jaguar to reach speeds of Mach 1.4

"CONSTRUCTED WITH AN ALUMINIUM AIRFRAME, THE JAGUAR CAN HANDLE EXTREME WEATHER CONDITIONS AND SPEEDS OF UP TO 1,593 KILOMETRES PER HOUR"

THE BOURNEMOUTH AVIATION MUSEUM

In August 1999, the Bournemouth Aviation Museum was established on the same site as Bournemouth Airport. Originally part of the now defunct Jet Heritage Museum, the centre strives to provide a hands-on experience for all visitors. The centre has 15 aircraft, ranging from military jets to a Boeing 737. It houses aircraft from all eras such as a Gloster Meteor from 1944 and the SEPECAT Jaguar. Visitors are encouraged to jump in the cockpit and have a go in a truly interactive experience.

JAGUARS IN WAR

INDIA

The biggest non-European customer for the Jaguar used the aircraft extensively in the three-year Indian Peace Keeping Force in Sri Lanka. They were also used to launch laser-guided bombs in the 1999 Kargil War with Pakistan and in an anti-ship role, a function it rarely undertook for the UK and France. They are still in use but there are plans to upgrade them.

UK

The Jaguar was an effective member of the RAF for many years. It undertook the first bombing raid in Europe since World War II against Bosnian Serb forces and also saw action in the Gulf War, designating targets for laser-guided bombs. It was meant to serve in the 2003 Iraq War but was pulled out after Turkey refused the use of its air bases.

FRANCE

The Armee de l'Air (French Air Force) utilised the Jaguar in combat operations in Chad, where they supported the country against Libyan forces. The fighter was involved in various operations such as the raid on Ouadi Doum airstrip and also flew for the country in the Gulf War and Kosovo. Jaguars were effectively replaced by the Dassault Rafale in 2005.

Images: Bournemouth Aviation Museum, Getty

TYPES OF JAGUAR

WHAT VARIATIONS OF THE JAGUAR DID SEPECAT PRODUCE?

Since its maiden flight, there have been 23 variants of the Jaguar, from trainers to naval versions to ground attack models.

A: Deployed by the French Air Force (FAF), the A was first flown in 1969 and is a single-seat low level attack aircraft. 160 were made in total.

B: First flown in 1971, this two seat trainer model could also be employed in a strike role in ground attack missions. 39 were made.

E: This trainer was a simple update of the B and 41 were used by the FAF.

S: One of the most technologically advanced of the Jaguar range, the S utilised a laser ranger and a marked target seeker to help its missiles find their target.

M: A naval version of the Jaguar that was used in sea-based patrol missions. It had unique landing gear with two nose wheels and a single main wheel to help it land on carriers.

T4: Another one trainer aircraft, the T4 was an upgrade of the B range with more modern capabilities.

The Jaguar's versatility is shown by the number of variants produced

REPLACING THE JAGUAR

PANAVIA TORNADO ADV INTERCEPTOR

A multirole aircraft, the Tornado could be used for air support, long-range interception, counter air attack and defence suppression. Initially intended to combat Soviet bombers in the height of the Cold War, it later served in the Gulf War.

DASSAULT RAFALE

Constructed by the French in 1986, the greatest feature of the Rafale is its SPECTRA electronic warfare system. The Rafale uses the software as part of virtual stealth technology. It replaced the American built Vought F-8 Crusader.

EUROFIGHTER TYPHOON

First flown in 1994 but introduced in 2003, the Eurofighter is the result of Britain, Germany, Italy and Spain desiring a new breed of fighter. Able to carry six bombs and six missiles, it is as much a gunship as a fighter. Only 15 per cent of the aircraft is metal, giving it superb stealth capabilities.

FIGHTER JET WEAPONS

WHEN OUT ON PATROL, THE JAGUAR COULD PACK A PUNCH IF THINGS TURNED NASTY WITH ARMAMENT FROM MACHINE GUNS TO NUCLEAR BOMBS

DEFA CANNON

AS30 AIR-TO-GROUND MISSILE

R.550 MAGIC AIR-TO-AIR MISSILE

The Jaguar's all-digital cockpit was incredibly advanced when it was first constructed

"THE AIRCRAFT IS COVERED IN AN ALL-OVER, WRAP-ROUND CAMOUFLAGE THAT HELPS THE JAGUAR AVOID DETECTION"

WE.177 NUCLEAR BOMB

MARTEL ANTI-RADIATION MISSILE

AIM-9 SIDEWINDER

SEA HARRIER

Before being retired in 2006, the Sea Harrier dominated the subsonic jet fighter field, changing the dynamics and operation of the strike fighter role forever

The British Aerospace Sea Harrier was the purpose-built naval variant of the Hawker Siddeley Harrier strike fighter, an aircraft that was famed for its vertical take-off and landing (VTOL) and short take-off and vertical landing (STOVL) capabilities. It worked by adopting the revolutionary single-engine thrust vectoring technology of the regular harrier (see 'Degrees of power' boxout) and partnering it with a modified fuselage – in order to allow the installation of the superb Blue Fox radar system – bubble-style canopy (larger, allowing greater visibility) and a significantly improved arms load out.

These factors, partnered with the aircraft carrier's ability to launch the aircraft from its ski-jump, allowed the Sea Harrier to perform to a high standard at sea, carrying more weight, detecting enemies sooner and taking them down quickly and efficiently. This was demonstrated most vividly during the Falklands War of 1982, when 28 Sea Harriers operating off British aircraft carriers shot down 20 Argentine aircraft in air-to-air combat without suffering a single loss. The Sea Harrier squadron achieved this due to their high manoeuvrability and tactics while in dogfights – for example, braking/changing direction fast by vectoring their thrust nozzles while in forward flight – as well as their pilots' superior training and early-warning/detection systems.

THRUST VECTORING

To achieve VTOL capabilities, the Sea Harrier's engine thrust was directed through four vectoring nozzles, which could rotate through 98.5 degrees from vertically downwards to horizontal.

PROTECTION

Due to the testing marine operating conditions, parts of the Sea Harrier were changed to use corrosion-resistant alloys or protective coatings.

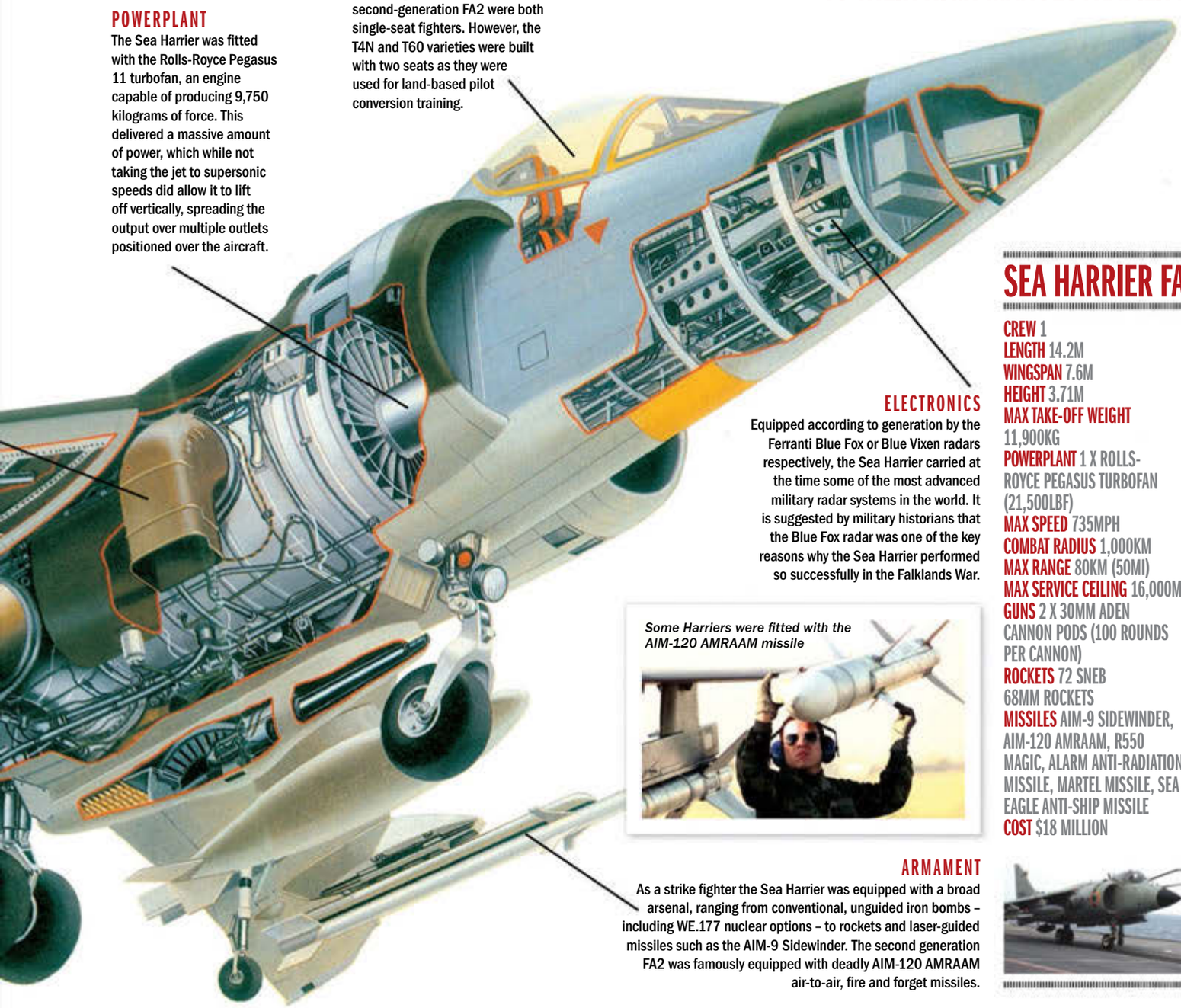
Second-generation Sea Harriers on board an aircraft carrier in the Persian Gulf

Two Indian Navy Sea Harriers fly alongside a US Navy F/A-18F Super Hornet

"THE SEA HARRIER SQUADRON ACHIEVED THIS DUE TO THEIR HIGH MANOEUVRABILITY"

POWERPLANT
The Sea Harrier was fitted with the Rolls-Royce Pegasus 11 turbofan, an engine capable of producing 9,750 kilograms of force. This delivered a massive amount of power, which while not taking the jet to supersonic speeds did allow it to lift off vertically, spreading the output over multiple outlets positioned over the aircraft.

CREW
The first-generation Sea Harrier FRS1 and second-generation FA2 were both single-seat fighters. However, the T4N and T60 varieties were built with two seats as they were used for land-based pilot conversion training.



ELECTRONICS
Equipped according to generation by the Ferranti Blue Fox or Blue Vixen radars respectively, the Sea Harrier carried at the time some of the most advanced military radar systems in the world. It is suggested by military historians that the Blue Fox radar was one of the key reasons why the Sea Harrier performed so successfully in the Falklands War.

Some Harriers were fitted with the AIM-120 AMRAAM missile

ARMAMENT
As a strike fighter the Sea Harrier was equipped with a broad arsenal, ranging from conventional, unguided iron bombs – including WE.177 nuclear options – to rockets and laser-guided missiles such as the AIM-9 Sidewinder. The second generation FA2 was famously equipped with deadly AIM-120 AMRAAM air-to-air, fire and forget missiles.

SEA HARRIER FA2

CREW 1
LENGTH 14.2M
WINGSPAN 7.6M
HEIGHT 3.71M
MAX TAKE-OFF WEIGHT 11,900KG
POWERPLANT 1 X ROLLS-ROYCE PEGASUS TURBOFAN (21,500LBF)
MAX SPEED 735MPH
COMBAT RADIUS 1,000KM
MAX RANGE 80KM (50MI)
MAX SERVICE CEILING 16,000M
GUNS 2 X 30MM ADEN CANNON PODS (100 ROUNDS PER CANNON)
ROCKETS 72 SNEB 68MM ROCKETS
MISSILES AIM-9 SIDEWINDER, AIM-120 AMRAAM, R550 MAGIC, ALARM ANTI-RADIATION MISSILE, MARTEL MISSILE, SEA EAGLE ANTI-SHIP MISSILE
COST $18 MILLION

DEGREES OF POWER

GIVING THE SEA HARRIER LIFT OFF

The real showpiece and reason for the lengthy success of the Sea Harrier was its utilisation of the its revolutionary Pegasus engine partnered with thrust vectoring nozzles. These nozzles could be rotated by the pilot through a 98.5 degree arc, from the conventional aft (horizontal) positioning as standard on aircraft, to straight down, allowing it to take off and land vertically as well as hover, to forward, allowing the Harrier to drift backwards. All nozzles were moved by a series of shafts and chain drives, which insured that they operated in unison (crucial for maintaining stability) and the angle and thrust was determined in-cockpit by the pilot.

This flexibility of control and placement meant that the Sea Harrier was highly manoeuvrable while in the air and could be landed and launched from almost anywhere.

The Sea Harrier's vectoring nozzle in aft position

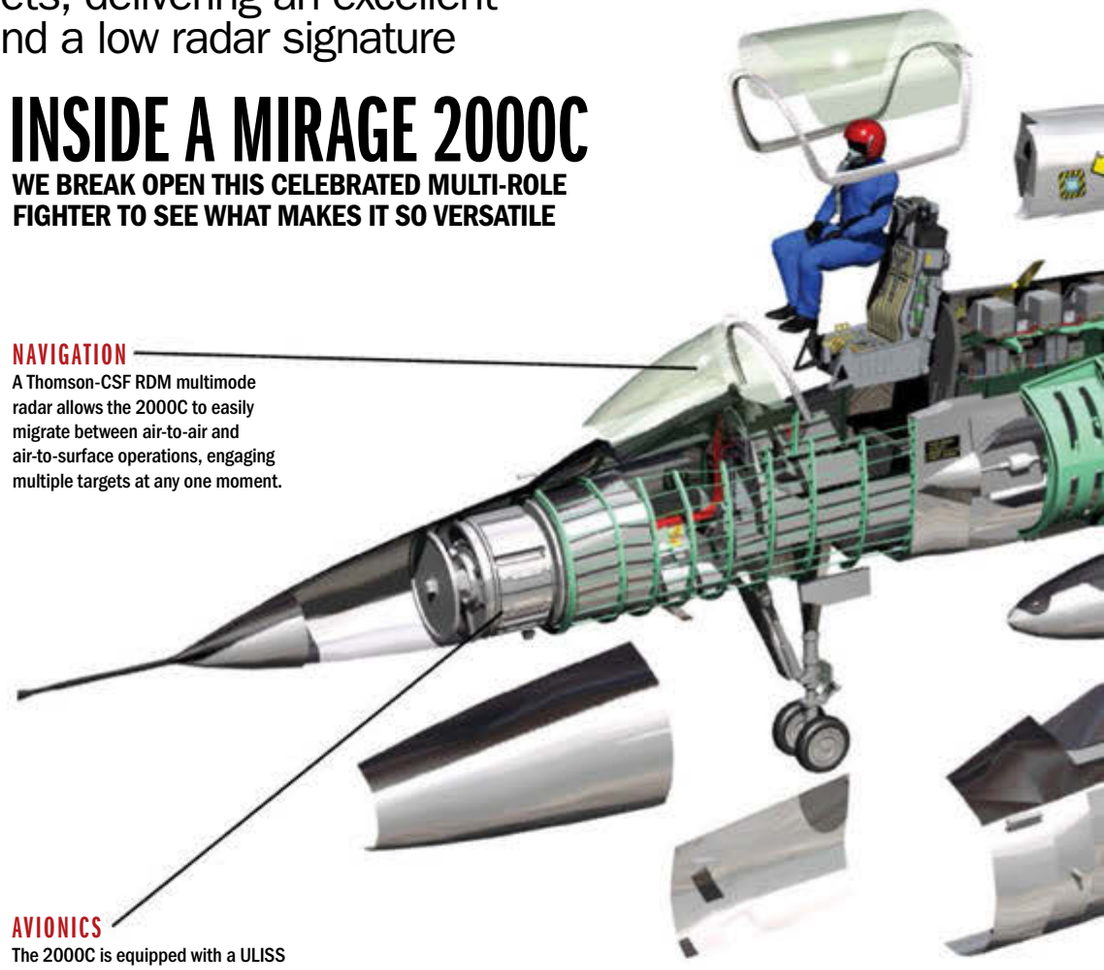
DASSAULT MIRAGE 2000

A lightweight aircraft boasting diverse multi-role functionality, the Dassault Mirage 2000 epitomises fourth-generation fighter jets, delivering an excellent high-speed flight profile and a low radar signature

Two Mirage 2000Cs during a Baltic air policing deployment role

INSIDE A MIRAGE 2000C

WE BREAK OPEN THIS CELEBRATED MULTI-ROLE FIGHTER TO SEE WHAT MAKES IT SO VERSATILE



NAVIGATION

A Thomson-CSF RDM multimode radar allows the 2000C to easily migrate between air-to-air and air-to-surface operations, engaging multiple targets at any one moment.

AVIONICS

The 2000C is equipped with a ULISS 52 inertial navigation system, TRT radio altimeter, Type 2084 digital flight controller and Sextant Avionique Type 90 air data computer.

Despite being overshadowed by more glamorous aircraft over the last 30 years, the Dassault Mirage 2000 series of multi-role fighter jets has quietly delivered excellent functionality and cost efficiency for its operators, which as of 2012, includes nations from Europe, through the Middle East and on to Asia. Of course, it is not all über-hyped eco-credentials and safety features that have heightened and maintained the Mirage's popularity among air forces worldwide – but primarily its ability to deliver extreme lethality to air, sea and land targets alike with a whole arsenal of deadly weapons.

We're talking nine hardpoints, two powerful revolving 30-millimetre (1.2-inch) cannons, multiple Matra rocket pods each capable of launching 18 68-millimetre (2.7-inch) unguided rockets, two R550 Magic short-range air-to-air missiles, two Super 530 medium-range air-to-air missiles, two Exocet AM-39 anti-ship missiles, two AS-30L, laser-guided air-to-ground missiles and the motherload… the ability to deliver a single ASMP tactical nuclear cruise missile into the heart of any region within a 300-kilometre (186-mile) range. As mentioned, when you have this vastness and flexibility of payload on offer, maintenance becomes less of an issue, as let a 2000-series out of the hangar and soon there are no targets left to hit.

Complementing this insane level of firepower are equally mind-boggling performance characteristics, something granted by the collaboration of a slick delta-wing planform and explosive SNECMA M53-P2 afterburning turbofan powerplant. The M53-P2 enables the Mirage 2000 to hit a top speed of 2,400 kilometres (1,500 miles) per hour and allows it to climb to an altitude of 16,154 metres (53,000 feet) in a minute. The engine's power – which produces on afterburner a maximum of 98 kilonewtons (22,000 pounds force) of thrust – is enhanced thanks to the 2000's adjustable half-cone air intakes, which provide inclined shocks of air pressure for an incredibly efficient air intake at high speeds.

And it is at these high speeds that the Mirage 2000's delta-wing planform really comes into its own, delivering snake-like agility and fluidity of movement. This works because the triangular rearward sweep angle of the jet's wings vastly lowers the airspeed normal to their leading edges, while simultaneously ensuring the over-wing speed remains less than the speed of sound. This, combined with their inherent large surface area, grants huge lift and minimal wing per unit loading and, as such, super-high airframe manoeuvrability.

This phenomenal agility is further enhanced by the Mirage being designed with an offset

Despite the Mirage 2000 production programme ending in 2007, many are still in active service today

"THE DOUBLE-WHAMMY OF AWESOME PERFORMANCE AND INCREDIBLE FIREPOWER ENSURES THAT THE MIRAGE IS STILL BEING USED TODAY"

DASSAULT MIRAGE 2000C

CREW 1
WINGSPAN 9M (29FT)
LENGTH 14M (47FT)
HEIGHT 5M (17FT)
POWERPLANT 1 X SNECMA M53-P2 TURBOFAN (64KN/14,388LBF)
MAX SPEED MACH 2.2 (2,400KM/H; 1,500MPH)
MAX RANGE 1,550KM (963MI)
MAX ALTITUDE 17,060M (59,000FT)
ARMAMENT 2 X 30MM CANNONS, 2 X 68MM MATRA ROCKET PODS, 2 X MATRA R550 MAGIC-IIS, 2 X AM-39 EXOCETS, 2 X AS-30L LASER-GUIDED MISSILES, 1 X ASMP TACTICAL NUCLEAR CRUISE MISSILE, 9 X MK 82 FREE-FALL BOMBS

STRUCTURE

The Mirage 2000 series works from a delta-wing planform, which offers superior high-speed agility. In addition, the model has multi-spar metal wings and carbon-fibre-skinned elevons with alloyed, honeycomb cores.

POWERPLANT

The Mirage's SNECMA M53 turbofan engine can produce a dry thrust of 64kN (14,388lbf) and a whopping 98kN (22,000lbf) in afterburner. The top speed rests at 2,400km/h (1,500mph).

ARMAMENT

Aside from two 30mm (1.2in) revolver-type cannons, the 2000C can be fitted with a variety of missiles and bombs over its nine hardpoints. These range from Matra Magic-IIs through to a nuclear cruise missile.

A Mirage 2000B variant pre-takeoff. The jet can climb 16,154m (53,000ft) in 60 seconds

neutral point, which is pushed further forward on the jet than its centre of gravity. This means that the aircraft is fundamentally unstable during flight, which though it sounds dangerous, enables the pilot to make tighter, physics-bending moves.

Indeed, the double-whammy of awesome performance and the potential to deal a massive amount of damage when cleared for takeoff is ensuring that, despite the Mirage production programme ceasing several years ago, the jet is still being actively used today, representing countries both at home and abroad. A good example of this continued respect for the aircraft's combat abilities can be seen in France's recent deployment of Mirage 2000s in the enforcement of the no-fly zone in Libya in 2011.

STEALTH BOMBER

The B-2 is extraordinary, both in terms of appearance and design

The 'flying wing' shaped Stealth Bomber is a unique aircraft that's designed to make it as invisible as possible. Its shape means there are very few leading edges for radar to reflect from, reducing its signature dramatically. This is further enhanced by the composite materials from which the aircraft is constructed and the coatings on its surface. These are so successful that despite having a 172-foot wingspan, the B-2's radar signature is an astounding 0.1m2.

The B-2's stealth capabilities, and aerodynamic shape, are further enhanced by the fact its engines are buried inside the wing. This means the induction fans at the front of the engines are concealed while the engine exhaust is minimised. As a result, the B-2's thermal signature is kept to the bare minimum, making it harder for thermal sensors to detect the bomber as well as lowering the aircraft's acoustic footprint.

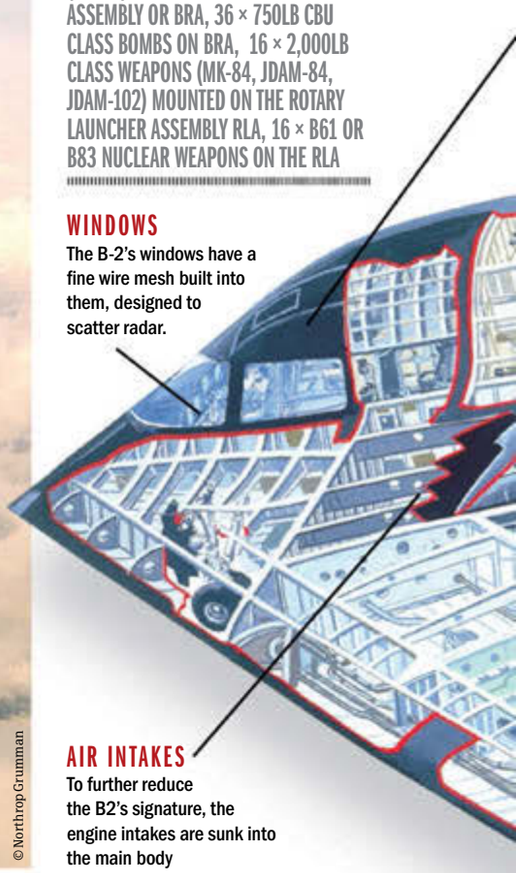
The design also means the B-2 is both highly aerodynamic and fuel efficient. The B-2's maximum range is 6,000 nautical miles and as a result the aircraft has often been used for long-range missions, some lasting 30 hours and in one case, 50. The B-2 is so highly automated that it's possible for a single crew member to fly while the other sleeps, uses the lavatory or prepares a hot meal and this combination of range and versatility has meant the aircraft has been used to research sleep cycles to improve crew performance on long-range missions.

Despite this, the aircraft's success comes with a hefty price tag. Each B-2 costs $737 million and must be kept in a climate-controlled hangar to make sure the stealth materials remain intact. These problems aside though, the Spirit is an astonishing aircraft, even if, chances are, you won't see one unless the pilots want you to…

You may not see the plane, but you'll see the bombs

B-2 SPIRIT

MANUFACTURER: NORTHROP GRUMMAN
YEAR DEPLOYED: 1993
LENGTH 69FT
WINGSPAN 172FT
HEIGHT 17FT
WEIGHT (EMPTY / MAX) 158,000LB / 336,500LB
UNIT COST $737,000,000
MAX SPEED MACH 0.95 (604MPH)
PROPULSION GENERAL ELECTRIC F118-GE-100 NON-AFTERBURNING TURBOFANS
CEILING 50,000FT
ARMAMENT THE B-2 HAS TWO INTERNAL BAYS CAPABLE OF HOLDING 50,000LB OF ORDNANCE.
PAYLOADS 80 × 500LB CLASS BOMBS (MK-82) MOUNTED ON THE BOMB RACK ASSEMBLY OR BRA, 36 × 750LB CBU CLASS BOMBS ON BRA, 16 × 2,000LB CLASS WEAPONS (MK-84, JDAM-84, JDAM-102) MOUNTED ON THE ROTARY LAUNCHER ASSEMBLY RLA, 16 × B61 OR B83 NUCLEAR WEAPONS ON THE RLA



WINDOWS
The B-2's windows have a fine wire mesh built into them, designed to scatter radar.

AIR INTAKES
To further reduce the B2's signature, the engine intakes are sunk into the main body

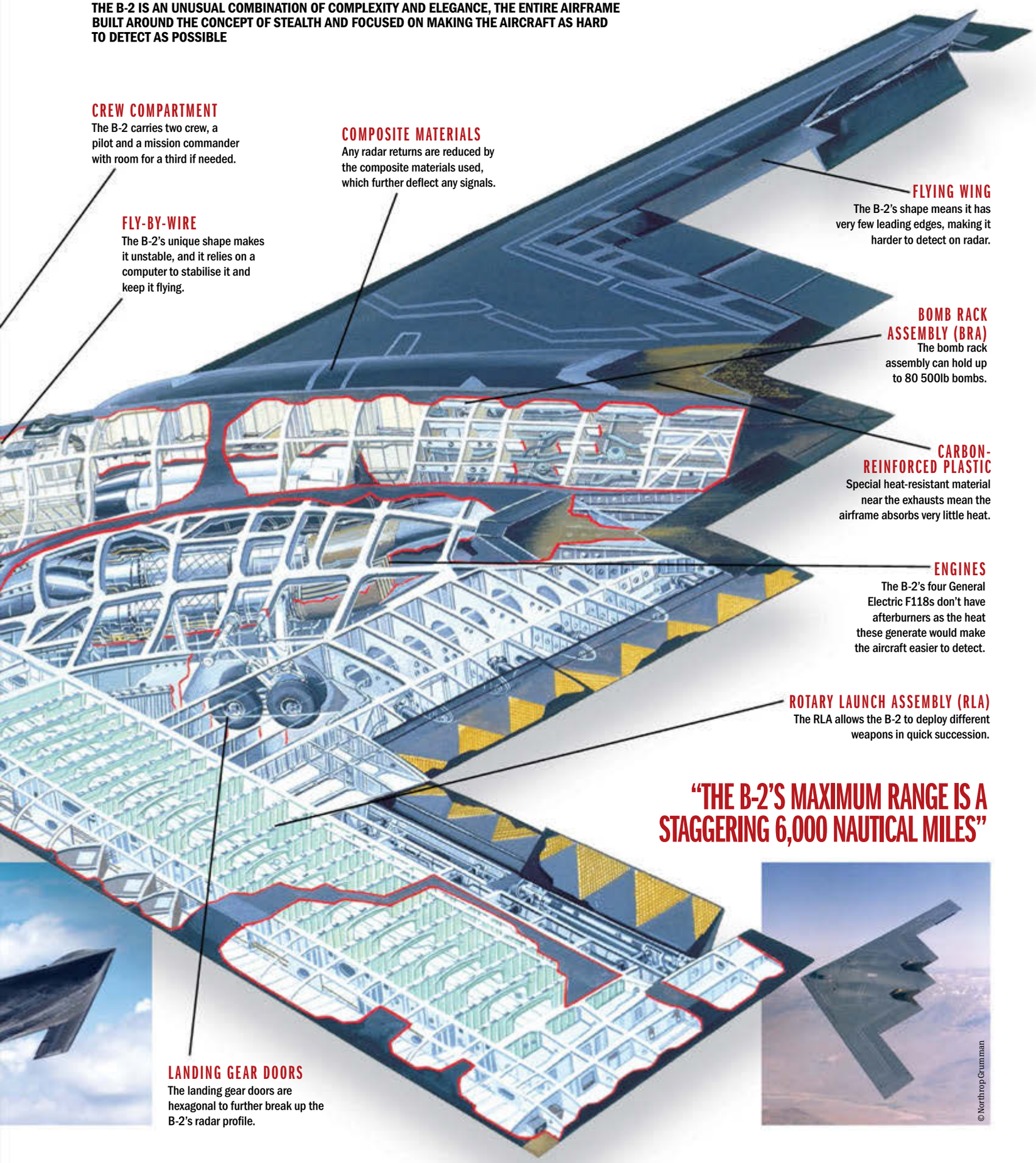
The B-2's engines are buried within the wing

Landings are fine, if the tower spots you coming…

Not one you're likely to find in your I-Spy book…

GHOST WORKS: INSIDE THE SPIRIT

THE B-2 IS AN UNUSUAL COMBINATION OF COMPLEXITY AND ELEGANCE, THE ENTIRE AIRFRAME BUILT AROUND THE CONCEPT OF STEALTH AND FOCUSED ON MAKING THE AIRCRAFT AS HARD TO DETECT AS POSSIBLE



CREW COMPARTMENT
The B-2 carries two crew, a pilot and a mission commander with room for a third if needed.

FLY-BY-WIRE
The B-2's unique shape makes it unstable, and it relies on a computer to stabilise it and keep it flying.

COMPOSITE MATERIALS
Any radar returns are reduced by the composite materials used, which further deflect any signals.

FLYING WING
The B-2's shape means it has very few leading edges, making it harder to detect on radar.

BOMB RACK ASSEMBLY (BRA)
The bomb rack assembly can hold up to 80 500lb bombs.

CARBON-REINFORCED PLASTIC
Special heat-resistant material near the exhausts mean the airframe absorbs very little heat.

ENGINES
The B-2's four General Electric F118s don't have afterburners as the heat these generate would make the aircraft easier to detect.

ROTARY LAUNCH ASSEMBLY (RLA)
The RLA allows the B-2 to deploy different weapons in quick succession.

"THE B-2'S MAXIMUM RANGE IS A STAGGERING 6,000 NAUTICAL MILES"

LANDING GEAR DOORS
The landing gear doors are hexagonal to further break up the B-2's radar profile.

MIKOYAN MIG-29

Russia's primary fighter jet combines a host of advanced tech to create an agile and deadly aircraft

Often overlooked in the west due to its Soviet Union origins in the Eighties, the Mikoyan MiG-29 is one of the world's most prolific fighter jets, with over 1,600 units in operation around the globe. For perspective, there are just over 300 Eurofighter Typhoons currently in operation, a number that is unlikely to ever exceed the 500 mark.

So why is this Russian plane so successful? For starters, it's great value for money – £18 million ($29 million), compared to the £64.8 million ($104.6 million) Typhoon.

The MiG-29 is a fourth-generation fighter jet designed for an air supremacy role, which involves infiltrating and seizing enemy airspace through force. It comes in a range of variants, with both legacy and current production models in operation, and has seen significant combat throughout its 19-year service, including deployment in the Persian Gulf War.

The aircraft is built around an aluminium airframe, which is bolstered with advanced composite materials. This airframe is designed for up to 9g manoeuvres, making the jet insanely agile and easy to fly for skilled pilots – hence why it's often used at air shows.

Surrounding the airframe is a sculpted titanium/aluminium alloy fuselage that tapers in from a wide rear to a raised cockpit and elongated nose cone. From the fuselage extends the mid-mounted swept wings, which are installed with leading-edge root extensions.

The MiG-29 is powered by two widely spaced Klimov RD-33 afterburning turbofans that, besides granting a top speed of 2,400 kilometres (1,490 miles) per hour, also reduce effective wing loading thanks to their spacing. The engines are fed by an internal fuel system that parses its total reserves down into a series of sub-tanks.

The MiG-29 comes packing a vast arsenal too. Each jet is fitted with seven hardpoints capable of carrying an array of weapons, or external fuel tanks for longer missions.

A MiG-29 from the Serbian Air Force takes off

ANATOMY OF A MIG-29B

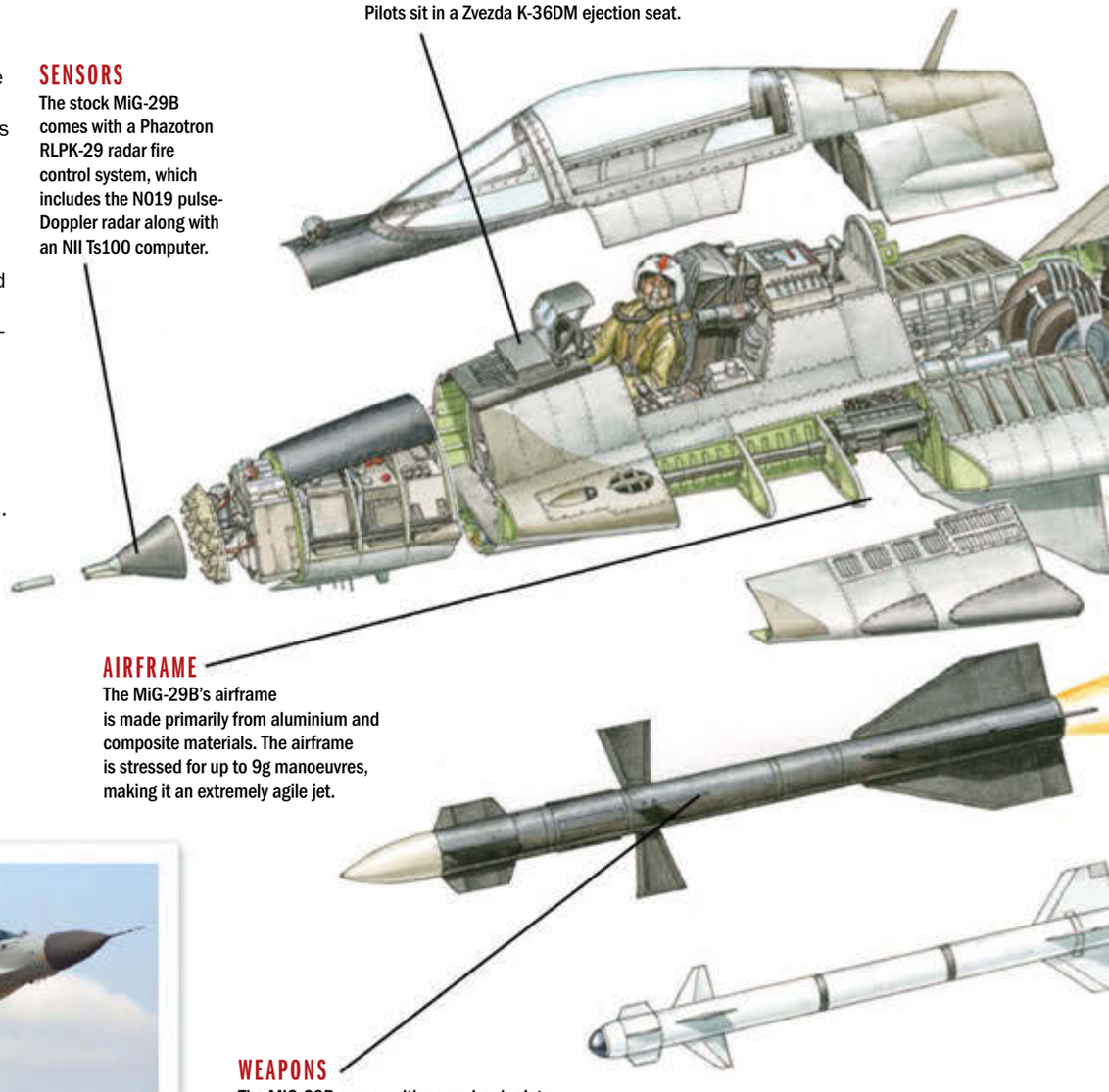
THE ESSENTIAL HARDWARE OF THIS RUSSIAN AIR SUPERIORITY FIGHTER REVEALED

COCKPIT

The MiG-29B's cockpit has a bubble canopy and comes equipped with a conventional centre stick, left-hand throttle controls and a heads-up display. Pilots sit in a Zvezda K-36DM ejection seat.

SENSORS

The stock MiG-29B comes with a Phazotron RLPK-29 radar fire control system, which includes the N019 pulse-Doppler radar along with an NII Ts100 computer.



AIRFRAME

The MiG-29B's airframe is made primarily from aluminium and composite materials. The airframe is stressed for up to 9g manoeuvres, making it an extremely agile jet.

WEAPONS

The MiG-29B comes with seven hardpoints, each capable of carrying a selection of arms (such as R-73 air-to-air missiles) and bombs. In addition, it carries a single GSh-30-1 30mm (1.2in) cannon.

MIKOYAN MIG-29

CREW 1
LENGTH 17.4M (57FT)
WINGSPAN 11.4M (37.4FT)
HEIGHT 4.7M (15.4FT)
POWERPLANT 2 X KLIMOV RD-33 AFTERBURNING TURBOFANS
MAX SPEED MACH 2.25 (2,400KM/H; 1,490MPH)
MAX RANGE 1,430KM (888MI)
MAX ALTITUDE 18,013M (59,100FT)
HARDPOINTS 7
MAX PAYLOAD 3,500KG (7,720LB)

POWERPLANT

The fighter jet comes installed with two Klimov RD-33 afterburning turbofans, which are widely spaced to reduce wing loading and improve manoeuvrability. They each deliver 8,290kgf (18,277lbf) on afterburner.

WINGS

The MiG-29B features mid-mounted, swept wings with blended leading-edge root extensions swept at 40°, as well as automatic leading-edge slats and trailing-edge flaps.

MiG-29s can reach a top speed of 2,400 kilometres (1,490 miles) per hour

"ONE OF THE WORLD'S MOST PROLIFIC FIGHTER JETS, THERE ARE OVER 1,600 UNITS IN OPERATION AROUND THE GLOBE"

V-22 OSPREY

The class-bending military aircraft that demolishes the aviation rulebook

When work began on the concept for the V-22 Osprey over 25 years ago, it's unlikely that anyone thought it would end like this. Boasting twice the speed, three times the payload, five times the effective range and with an ability to dominate the skies from over twice the altitude, the V-22 doesn't just eclipse the competition, it blows it out of the 21st Century. Taking the hard rules once defined by the physical limitations of rotorcraft – that of range, speed and flexibility – this fusion of plane and helicopter has forgotten them all and changed the nature of war permanently.

The statistics tell the same story. Powered by two state-of-the-art tilt rotor engines developed by Rolls-Royce, each of which delivering a bombastic 6,150hp, the V-22 Osprey easily reaches a scorching top speed of 315mph, which for its size is colossal. With so much raw power comes the ability to reach heights of up to 25,000ft, as well as having a range of 879nmi, more than double that of the previous first choice military workhorse the CH-47 Chinook.

So how is this phenomenal performance achieved? The answer lies in the Osprey's revolutionary tilt rotor engines, of which it is the world's first adopter in full-scale production. Operating in roughly the same way as the rotatable jets utilised on the RAF Harrier, the V-22 – through its adjustable rotors – allows for the vertical flight/take-off capabilities of helicopters with the speed, range, altitude and endurance of fixed-wing aircraft. This is good, for the V-22 Osprey is built for war, dirty nomadic modern warfare, and as a machine borne out of conflict, it knows how to defend itself.

When things get sticky the V-22 can sport a front/belly-mounted turret that provides 360-degree coverage of the battlefield for its three-barrel 7.62mm minigun, as well as deploying a ramp-mounted gun emplacement when grounded or airborne, perfect for raining death upon enemies. This is all well and good in attack you may say, but what about defence? Well, no problem there either. As well as what the handbook lists as an 'inherent and intentionally designed ballistic tolerance', the Osprey can take a tremendous amount of damage thanks to its bulletproof armour, turning it into a multi-mission juggernaut.

For a piece of kit that looks like it is more at home in a futuristic James Cameron movie than in the real world, the V-22 is actually in operation right now in both Afghanistan and Iraq, as well as seeing deployment in Africa as part of Exercise Flintlock last year. And when you take into account its biblical performance partnered with the fact that it was declared fully operational in March 2009, it is hard to see how the V-22 Osprey will not become a world-beater. The helicopter is dead. Long live the king!

Combat troops descend from the cabin of a V-22 in a training exercise

The V-22 is capable of high-speed low altitude flight

When taking-off the V-22's tilt-rotors remain in a vertical position

A V-22 in the middle of rotor transition

V-22 OSPREY VS CH-47 CHINOOK

ENGINE THRUST:	6,150HP X 2
MAX SPEED:	315MPH
MAX ALTITUDE:	25,000FT
MAX RANGE:	879NMI
CANNON:	THREE-BARREL 7.62MM MINIGUN

ENGINE THRUST:	3,750HP X 2
MAX SPEED:	183MPH
MAX ALTITUDE:	15,000FT
MAX RANGE:	400NMI
CANNON:	M240 7.62MM MACHINE GUN

INSIDE THE V-22 OSPREY

A VEHICLE WITH MORE THAN A FEW TRICKS UP ITS SLEEVE...

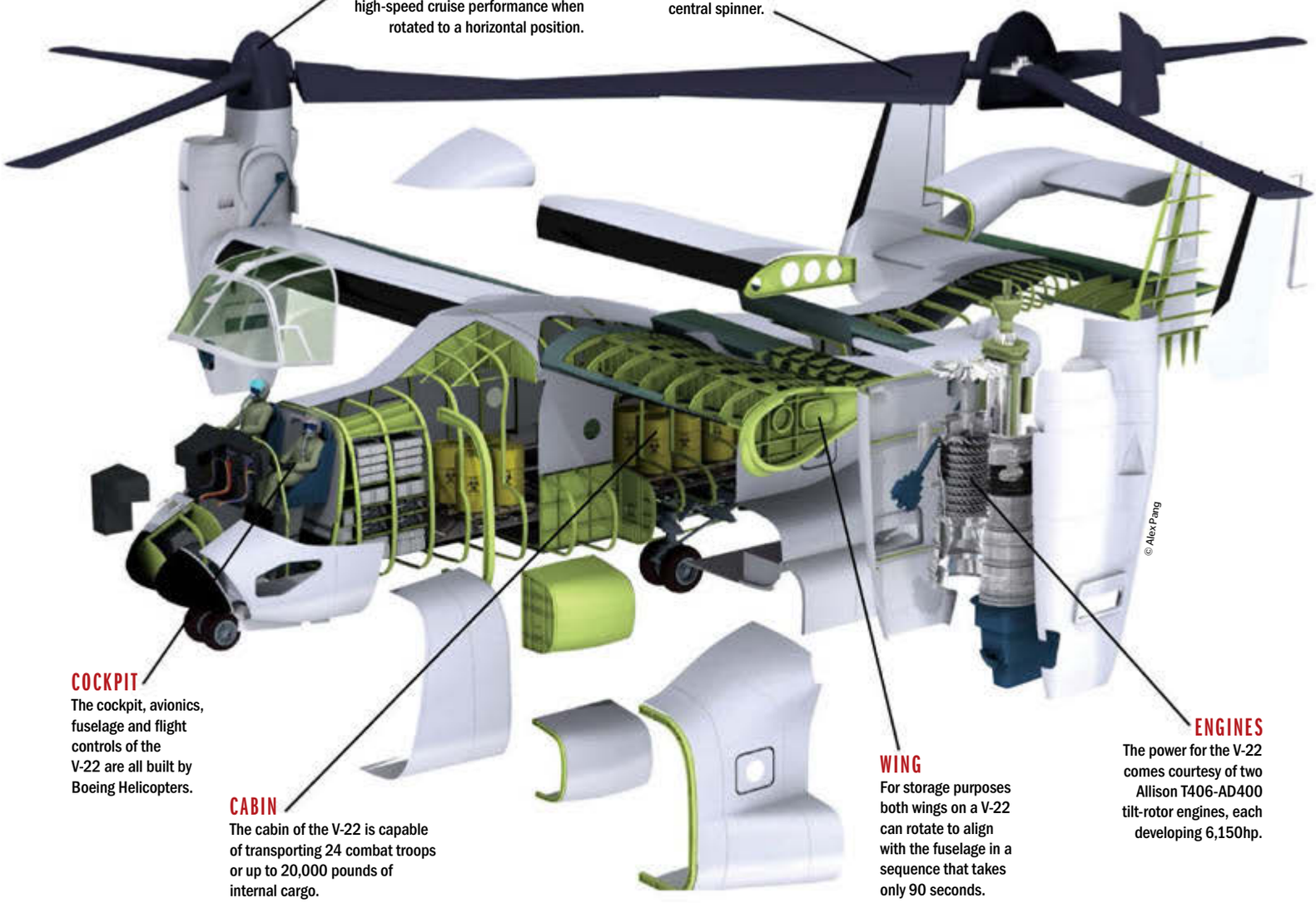
"THE V-22 EASILY REACHES A SCORCHING TOP SPEED OF 315MPH, WHICH FOR ITS SIZE IS COLOSSAL"

TILT-ROTOR TECHNOLOGY

The dual tilt-rotors of the V-22 allow for vertical take-off while also delivering high-speed cruise performance when rotated to a horizontal position.

THREE-BLADED ROTORS

Both sets of rotors are constructed out of graphite and fibreglass, rotating around a central spinner.



© Alex Pang

COCKPIT

The cockpit, avionics, fuselage and flight controls of the V-22 are all built by Boeing Helicopters.

CABIN

The cabin of the V-22 is capable of transporting 24 combat troops or up to 20,000 pounds of internal cargo.

WING

For storage purposes both wings on a V-22 can rotate to align with the fuselage in a sequence that takes only 90 seconds.

ENGINES

The power for the V-22 comes courtesy of two Allison T406-AD400 tilt-rotor engines, each developing 6,150hp.

EUROFIGHTER TYPHOON

The fighter plane that is so advanced it can't be flown by a human without the help of a computer

Picture courtesy of BAE Systems

The building of a Typhoon is certainly no easy task…

"IT IS IMPOSSIBLE FOR A HUMAN TO FLY THE PLANE WITHOUT THE AID OF A COMPLEX COMPUTER SYSTEM THAT MAKES CONSTANT ADJUSTMENTS TO THE WINGS' FLAPS"

EUROFIGHTER IN ACTION

JUST WHAT MAKES THE EUROFIGHTER SO FORMIDABLE?

The Eurofighter Typhoon may be the world's most advanced killing machine, but it is also an extraordinary symbol of peace and co-operation. After centuries of fighting, a number of European countries came together to produce this incredible aircraft.

From a plan started in 1979, the Eurofighter was developed by Germany, Italy, Spain and the UK (France was also briefly involved), and production is split between the four countries. At present there are plans to produce no less than 707 examples of the fighter jet. As well as the four core countries, the plane is also being used by other global air forces, including those of Austria, Saudi Arabia and Greece.

Why? Because it's the most technologically advanced fighter jet on the planet, and also the most capable.

It's what's known as a swing-role weapon system, which means it is capable of different operational tasks and can even switch from one to another on a single mission. For instance, it can be used as an air-to-air (short and medium range) fighter, while at the same time carrying large, long-range ground-attack weapons.

This flexibility is enhanced by the plane's incredible flying prowess. It boasts STOL (short take-off and landing) which means it needs just 700 metres to take-off or land (a 747 requires over 3,000 metres).

More impressively, the Eurofighter is incredibly manoeuvrable thanks in part to its 'relaxed stability' design, which is a reassuring way of saying that the aircraft is inherently unstable, especially at subsonic speeds. The plane's delta wings and small fore fins create a pressure (lift) point which is forward of the centre of gravity during subsonic flight. And that means it is impossible for a human to fly the plane without the aid of a complex computer system that makes constant adjustments to the wings' flaps. Once the speed of sound is broken, though, the pressure point moves back and the aircraft becomes much more stable (though the computer aids remain).

The same control systems also make the Eurofighter surprisingly easy to fly, freeing up the pilot to concentrate on tactical tasks.

No wonder the Eurofighter Typhoon is changing the way the world's air forces think about fighter planes.

ARMED AND READY FOR ACTION

The Eurofighter's formidable arsenal. The large items are, in fact, fuel tanks, although long-distance missiles can be fitted. The yellow devices are laser-powered bombs, while the smaller grey items are short-range air-to-air missiles. The thin armaments visible at the back of the fuselage are beyond-visual-range air-to-air missiles. There is also a Mauser BK-27 automatic cannon.

SMALL BUT PERFECTLY FORMED

The Eurofighter is remarkably compact – look at the size of the pilot in the cockpit to get an idea. The wingspan is 10.95 metres (less than that of a WWII Spitfire) and the length is 15.96 metres. This helps the aircraft to be incredibly agile, allowing it to change direction fast, as well as accelerate at an astonishing rate.

GIVING IT FULL THROTTLE

The Eurofighter's twin Eurojet turbofan engines combine a jet nozzle with a ducted fan. This allows efficiency at low speeds combined with relatively quiet operation. They are equipped with afterburners (shown in operation here) which inject neat fuel into the jet stream to give a short increase in power. However, the Eurofighter can cruise at supersonic speeds without afterburner help.

JOYSTICK
The Hands on Throttle and Stick (HOTAS) is a single joystick that gives fingertip control of up to 24 functions, including throttle, manoeuvring, target manipulation and weapon control.

RADAR
Advanced ECR-90 radar can track multiple targets at long range.

FRONT END
Includes in-flight refuelling probe.

COCKPIT
The high-tech cockpit is designed to make life easy for the pilot. Many functions are controlled by voice, while a head-up display puts essential data right in front of the pilot.

FORE WINGS
Made from titanium, these aid agility and responsiveness.

EJECTOR SEAT
Pilot can eject from the plane at speeds of up to 600 knots.

TWIN SEAT
A special twin-seater Eurofighter is used for training.

STEALTH FUSELAGE
A low frontal cross-section and the use of carbon fibre (70 per cent) and glass reinforced plastics (12 per cent) help ensure the Eurofighter can avoid detection by enemy radar. Metals, mostly aluminium and titanium, make up just 15 per cent of the body.

WEAPONS
There are 13 external weapon stations on the underside.

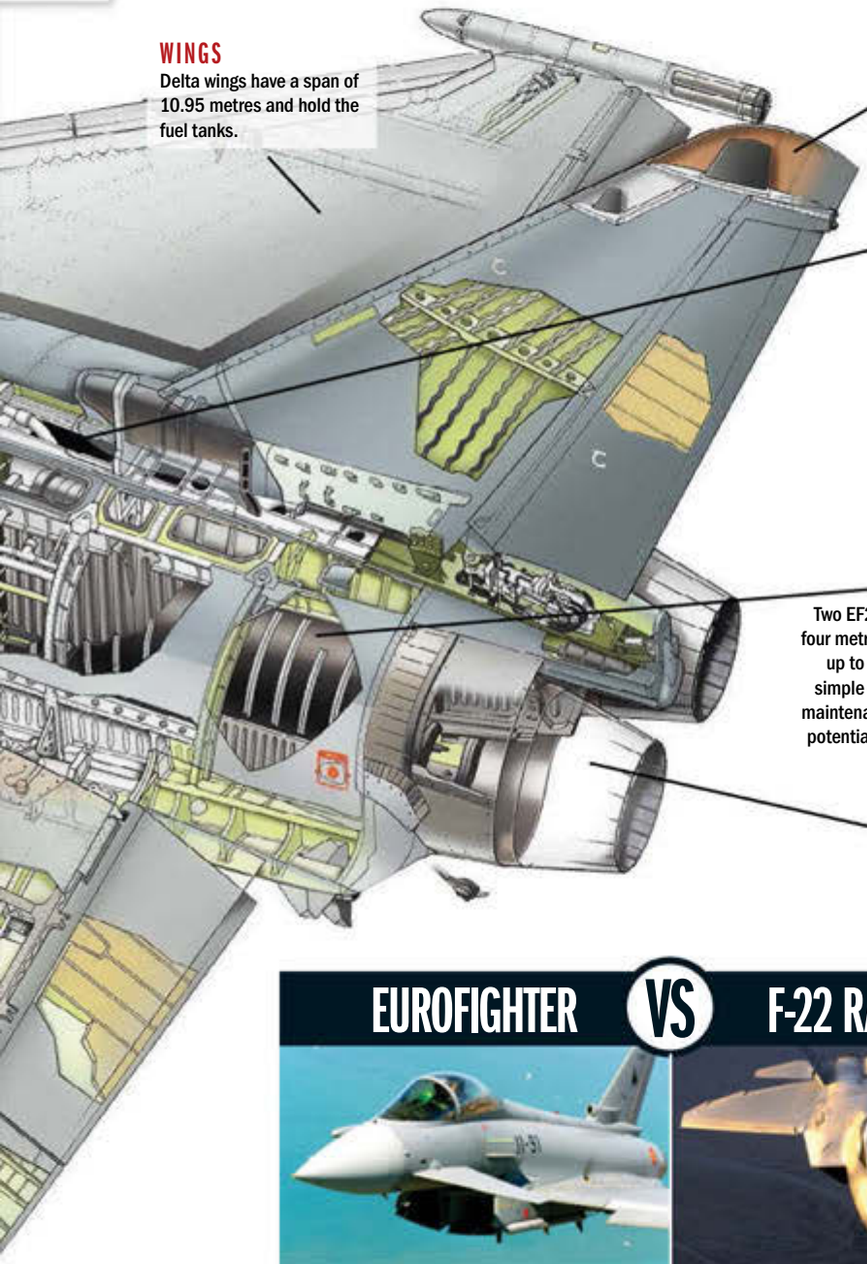
A stunning machine with awesome firepower

A top speed of 1,550mph means sights like this are common

All pictures courtesy of Geoffrey Lee from planefocus

TAKE A LOOK INSIDE THE EUROFIGHTER

Find out what makes the Eurofighter Typhoon the most advanced fighter on the planet



WINGS
Delta wings have a span of 10.95 metres and hold the fuel tanks.

TAIL FIN
Made from carbon fibre, it provides lateral stability and houses communication systems.

FUEL SYSTEMS
Fuel is stored in three tanks in the fuselage, a tank in each wing plus drop-tanks hung below each wing. An additional central drop-tank can be hung under the fuselage. When fully fuelled, the Eurofighter more than doubles in weight to around 23,500kg.

ENGINES
Two EF200 turbofan engines are four metres in length and produce up to 90KN of thrust each. The simple construction ensures low maintenance, while there is future potential to increase power by up to 15 per cent.

DISCREET
Engines create little smoke to reduce the risk of visual detection.

EUROFIGHTER VS F-22 RAPTOR

EUROFIGHTER		F-22 RAPTOR	
ENGINE THRUST:	20,000LBS	ENGINE THRUST:	35,000LBS
MAX SPEED:	1,550MPH	MAX SPEED:	1,500MPH
SUPERCRUISE:	840MPH	SUPERCRUISE:	1,220MPH
ALTITUDE:	65,000 FEET	ALTITUDE:	60,000 FEET
MAX RANGE:	2,045 MILES	MAX RANGE:	1,840 MILES
CANNON:	MAUSER BK-27 (150 ROUNDS)	CANNON:	M61A2 VULCAN (480 ROUNDS)

TYPHOON VS F-22 RAPTOR

After taking an in-depth look at Europe's most advanced fighter jet, the question of its performance against the American F-22 remains. It's an argument that rages on many an aviation-based internet forum and it's also one that is unlikely to ever have a definitive answer.

There's a strong argument for the F-22 Raptor having air dominance over the Typhoon because of its versatility: the Raptor has stealth capabilities and supercruises at a much higher speed than its European rival, which would give it the edge in all but a WVR (Within Visual Range) encounter. Due to its tiny radar signature the F-22 could obliterate the Typhoon before the latter was even aware of its presence. However, development of the third phase of the Typhoon will endow the fighter with full strike capabilities and improved radar to match the Raptor. The cost of the Raptor is also worth weighing against the Typhoon: initially £140 million for each Typhoon versus around $339 million (£212 million) for the Raptor, including research and development costs.

The most reliable comparison comes from General John P Jumper, Chief of Staff of the United States Air Force from September 2001 to September 2005 and one of the few pilots to have flown both aircraft. Speaking to the Air Force Print News before he retired, General Jumper said "It's like asking us to compare a NASCAR car with a Formula 1 car. They are both exciting in different ways, but they are designed for different levels of performance." He continued, "The Eurofighter is certainly, as far as smoothness of controls and the ability to pull (and sustain high g-forces), very impressive," he said. "The manoeuvrability in close-in combat was also very impressive." On the question of dominance though, Jumper stated "The F-22 Raptor has stealth and supercruise. It has the ability to penetrate virtually undetected because of (those) capabilities. It is designed to be a penetrating aeroplane. It can manoeuvre with the best of them if it has to, but what you want to be able to do is get into contested airspace no matter where it is." However it the real measure of success between the two planes could be a financial one. The US Senate has discontinued production of the F-22, with President Obama stating "at a time when we're fighting two wars and facing a serious deficit, [expanding the F-22] would have been an inexcusable waste of money". Conversely, the UK has committed to buying a third tranche of Eurofighters, perhaps making it a winner without even leaving the hanger.

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★ CREW: 190
★ MAX SPEED: 29 KNOTS

PROJECT 670 CHARLIE CLASS
★ NUMBER BUILT: 17
★ RETIRED: 1996

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